Agriculture Canada

FORAGE CROPS

in the Aspen Parklands of Western Canada

·HARVESTING·

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FORAGE CROPS
in the Aspen Parklands of Western Canada

· *HARVESTING* ·

Research Station Melfort, Saskatchewan

Research Branch
Agriculture Canada

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INTRODUCTION

Dans les années 1940 et 1950, les producteurs de fourrages de l'Ouest du pays avaient à leur disposition peu de méthodes de récolte. La plupart du temps, après la coupe, ils empilaient le foin long en meules ou le mettaient en balles. Quant à l'ensilage, ils le conservaient habituellement dans un silo-fosse ou dans un silo-couloir. Ils coupaient le foin sur pied au moyen d'une faucheuse à barre de coupe rectiligne, puis formaient des andains groupés en utilisant un râteau andaineur. Ensuite ils bottelaient le foin ou le ramassaient avec un râteau emmeuleur, le chargeaient à la fourche dans une charrette et le transportaient jusqu'à la grange où ils l'entreposaient au grenier ou le mettaient en balles. Cependant, peu importe la méthode utilisée, cette tâche exigeait beaucoup de main-d'oeuvre tant en termes d'heures-personnes par 100 tonnes que d'effort physique.

Vers la fin des années 1960 et au début des années 1970, les agriculteurs jouissaient déjà d'un choix beaucoup plus vaste de méthodes de récolte dont une grande partie requérait très peu, voire aucun travail manuel. On utilise encore beaucoup les presses à balles ordinaires. Il existe aussi des systèmes de manutention grâce auxquels les agriculteurs ramassent les balles et les empilent sans descendre du tracteur. On trouve aujourd'hui sur le marché plusieurs marques de presses à balles rondes qui forment des balles à centre dur ou mou. En raison du poids des balles, leur manutention doit être mécanisée. Il existe un large éventail de machines emmeuleuses qui produisent des meules en forme de pain ou de petit gâteau grâce à un système de compression, à l'action d'un ventilateur ou à l'effet de tassement de la machine en mouvement qui comprime le foin long ou haché en une masse conservant sa forme. On trouve aussi des râteaux emmeuleurs et des hacheurs désileurs qui servent à ramasser, à déplacer et à transporter les meules près des auges ou qui défont la meule et distribuent le foin dans les auges à alimentation automatique. On a aussi conçu des tours de déshydratation du fourrage qui permettent le ramassage du foin au champ à des taux d'humidité variant de 25 à 40 %, et ce, avec des pertes minimales. Le foin y est asséché avec de l'air chauffé ou non, jusqu'à l'obtention d'un taux d'humidité qui garantit un entreposage sûr. Pour charger et désiler ces tours, on utilise le même matériel (récolteuse-hacheuse, machine désileuse) que pour la préparation ordinaire de l'ensilage. Par ailleurs, ces tours permettent une mécanisation presque complète du chargement et du désilage.

Les systèmes d'ensilage composés de silos-fosses ou de silos-couloirs ont évolué. On trouve aujourd'hui des douves de béton ou des tours verticales en béton coulé et, depuis peu, des silos-presses qui comprime l'ensilage dans de très longs sacs de plastique. Jusqu'à maintenant, les silos à revêtement de métal ou de verre sont ceux qui conservent le mieux la valeur nutritive des fourrages, car l'apport d'oxygène y est réduit. Il existe aussi de l'équipement d'alimentation automatique.

Les progrès réalisés en matière de transformation et de conservation du fourrage (transformation physique, ammoniation et autres), d'une part, et l'utilisation de suppléments et d'additifs alimentaires stimulateurs de la croissance, d'autre part, permettent d'accroître le rendement des fourrages

obtenus grâce à certaines pratiques. Cependant, il est presque, voire complètement impossible d'augmenter celui du fourrage préparé au moyen d'autres méthodes. Par exemple, on peut moudre du foin en balle de piètre qualité au moyen d'un broyeur et augmenter ainsi l'ingestion et obtenir des gains plus rapides et plus importants. Cependant, comme on ne peut transformer mécaniquement l'ensilage régulier ou mi-fané, il ne reste plus qu'à accroître le rendement de l'animal en ajoutant à sa ration des aliments hautement énergétiques, comme le grain.

On met sans cesse au point de nouvelles techniques de récolte du fourrage. Ainsi, pour les balles rondes, on trouve maintenant une toile plastique qui réduit les pertes mécaniques pendant la manutention et protège les balles de la pluie. On a aussi mis au point une tige de 2,5 cm de diamètre que l'on attache au piston d'une ramasseuse-presse courante en vue de créer, au centre de la balle, un tunnel de séchage qui réduit les possibilités de détérioration du foin dont un côté est trop humide.

Depuis quelques années, un certain nombre de sociétés (New Idea, Gehl) fabriquent des modèles réduits de ramasseuses-presses. Ces machines forment des balles rondes d'environ 1,23 m (4 pi) de largeur, de 1,23 à 1,54 m (de 4 à 5 pi) de diamètre et de 250 à 500 kg (de 550 à 1 100 lb). Ces petites balles facilitent la manutention et l'alimentation, en particulier si les animaux sont nourris à l'étable ou par petits lots.

Aucun système de récolte du fourrage ne répond à toutes les exigences. Cependant, l'exploitant consciencieux et travailleur obtiendra de bons résultats peu importe la méthode choisie, à condition de la bien gérer, et ce, même si certaines pratiques sont plus sensibles aux intempéries. Par contre, un exploitant négligent préparera un produit de piètre qualité même avec l'équipement théoriquement le plus perfectionné. Une étude révèle d'ailleurs qu'il est possible de préparer un excellent ensilage avec plusieurs systèmes; il est cependant évident que pour obtenir un produit de bonne qualité, l'exploitant qui ne fait qu'empiler l'ensilage sur le sol et le recouvrir de plastique devra se montrer plus vigilant que celui qui possède un silo à revêtement de verre, dans lequel l'apport d'oxygène est réduit.

Dans tous les cas, il faut se rappeler que le fourrage récolté et conservé ne sera jamais d'aussi bonne qualité qu'au moment de la récolte. Plus le foin est mûr à la récolte, plus faible sera sa valeur nutritive et moins les animaux en consommeront quotidiennement. La baisse de la qualité et du taux d'ingestion indique qu'un animal est de moins en moins capable de combler ses besoins nutritionnels à partir du fourrage pendant son développement; l'éleveur devra donc accroître la proportion de grain et de suppléments protéiques dans les rations pour maintenir sa productivité.

La façon de récolter et d'entreposer les fourrages est un facteur déterminant de la valeur nutritive du produit et de la productivité globale de l'élevage. Le moment de la récolte détermine le rendement maximal et la qualité d'un fourrage particulier. À partir de ce moment, l'ampleur des pertes de rendement et de qualité dépendra de la détérioration des andains au champ, du taux d'humidité au moment de la préparation des balles et de l'ensilage, du soin apporté à la récolte et au transport du foin à entreposer, de l'exposition à l'oxydation (dans le cas de l'ensilage) et de l'exposition aux intempéries pendant l'entreposage et avant l'alimentation des bestiaux.

Les renseignements contenus dans la présente publication sont tirés d'une évaluation de nombreux systèmes de récolte qui a été faite à la Station fédérale de recherches agricoles de Melfort. Ces travaux ont été menés en collaboration avec le directeur et le personnel du Centre de recherches en génie rural, de la Ferme expérimentale centrale, à Ottawa, en 1974. Malgré certains détails sur les aspects techniques de quelques systèmes plus originaux mis à l'essai (tours de déshydratation du foin), les chercheurs se sont surtout intéressés à l'incidence des pratiques de récolte sur la valeur nutritive du foin et de l'ensilage et à la façon dont ces systèmes s'intègrent aux exploitations d'élevage de bovins.

Pour obtenir de plus amples renseignements sur les aspects techniques des méthodes de récolte, le lecteur pourra consulter la publication Forage Harvesting Methods, du ministère de l'Agriculture de la Saskatchewan, Regina, S4P 3V7, qui est le fruit des travaux de M. O.H. Friesen, ingénieur au ministère de l'Agriculture du Manitoba.

INTRODUCTION

The forage producer in western Canada had few harvesting methods available to him in the 1940's and 1950's. Hay was, for the most part, put up in the long form, either in loose stacks or as bales, while silage was usually put up in pit or bunker silos. The standing hay crop was moved using a reciprocating sickle bar mover and raked into windrows and either bunched and moved to the stack with a sweep, loaded by pitchfork onto a rack and transported to the barn for storage in the loft, or baled. In all cases the requirement for labor was high, both in terms of the number of man hours per 100 tons handled and the physical effort expended.

By the late 60's and early 70's there were considerable options in the selection of a forage harvesting system, many of which involved little or no need to physically handle the product. Use of the standard baler is still very popular and bale handling systems are available to pick up and stack bales without leaving the tractor seat. Many makes of round balers are now on the market, some forming hard-core and some soft-core bales. Because of the weight of these bales they have to be handled by mechanical means. A wide variety of stacking wagons is available to form loaf or cup-cake shaped stacks, some using compression systems, others relying on the force of the blower or the settling action of the moving wagon to compress the long or shredded hay into a form-retaining mass. Stack movers and shredder-unloaders are available to pick up, move and deliver the stack to the feeding site or to break the stack up and deliver the hay into bunk feeders. Hay drying towers have been developed to permit the forage to be picked up in the field at from 25 to 40% moisture with minimum leaf loss, and to dry the material, using heated or unheated air, to a moisture level at which the forage can be safely stored. These towers use the same field equipment (forage harvester, forage unloading wagons) as required for a silage operation and are almost completely automated both for filling and unloading.

Silage systems have expanded from the pit or bunker type to include concrete stave or poured concrete upright towers and more recently the silo press system which stores silage in large plastic tubes has been introduced. The oxygen limiting, metal or glass lined metal silos provide perhaps the most foolproof method for preserving forage nutrients yet devised. Equipment is available to permit "push button" feeding of silage to cattle.

New developments in forage processing and preservation (physical processing, ammoniation, etc.) and the use of supplements and growth promoting feed additives can enhance the productive potential of forages put up under some of the systems while with other harvesting methods little or no scope is available for improving the efficiency of forage utilization. For example, poor quality hays, in the standard bale, can be ground through a hammermill to increase feed intake, leading to faster and more efficient gains; while with silage or haylage, physical processing is not possible, and the only practical way to increase animal performance is by supplementing the ration with high energy feeds such as grain.

Nev forage harvesting techniques are constantly being developed. For example, a plastic mesh vrapping is nov available for round bales. This reduces physical loss during handling and helps to shed rain. Another development is the use of a 2.5 cm diameter rod, attached to the plunger on a standard baler which leaves a "drying tunnel" through the centre of the bale, thus reducing the possibility of spoilage when hay is baled on the "tough side".

In recent years, a number of companies (Nev Idea, Gehl) have manufactured smaller models of the round baler, which produce bales about 1.23 m (4') wide and from 1.23 to 1.54 m (4-5') in diameter, weighing from 250-500 kg (550-1100 lb.). The smaller bales are easier to handle and feed, particularly if barn feeding or feeding smaller lots of livestock.

No forage harvesting system is best under all conditions. The conscientious and dedicated operator can make any system vork if properly managed, although adverse weather conditions vill make it more difficult for some systems than for others. The careless operator can achieve a poor product even with the system, which in theory, should be best under the circumstances. One study revealed that it vas possible to make excellent silage using any of the several systems studied but it vas evident that more management input vas required using the pile type silo than when using the oxygen-limiting glass-lined silo if good quality silage vas to be obtained.

In all cases, one must remember that the feed coming out of a forage harvesting system is never going to be of any better quality than it was at the time of cutting. The more mature the forage at cutting, the lover will be its nutrient value and the less an animal will consume daily. The reduction in quality and the level of intake will mean that the animal will be less and less able to meet its nutrient requirements from forage as its maturity increases and that more and more grain, and possibly protein supplement, will have to be added to the ration to maintain a given level of productivity.

The manner in which forage crops are harvested and stored is a major factor in determining the feeding value of the product and the overall efficiency of the forage-livestock system. The timing of cutting determines the maximum yield and quality of a specific crop. From that point on, the extent of loss in yield and quality will depend on the weathering of the svath or vindrov in the field, the moisture content when packaged or ensiled, the care exercised in harvesting and transporting the material to storage, the exposure of the crop to oxidation (in the case of silage) and the exposure to weathering while in storage prior to being fed.

The information in this publication is derived from experience in assessing numerous harvesting systems at the Melfort Research Station since vork was initiated in cooperation with the Director and staff of the Engineering Research Services, Central Experimental Farm, Ottava, in 1974. While some details are presented on the engineering aspects of some of the more unique systems tested (hay drying tovers), the main focus is on the

effect of the systems on the feeding value of the hay or silage and how the system fits into a beef production enterprise.

For engineering aspects of forage harveting systems, the reader is referred to the bulletin "Forage Harvesting Methods", Saskatchevan Department of Agriculture, Regina, S4P 3V7, based on the work of O.H. Friesen, P.Eng., Manitoba Department of Agriculture.

HISTORY OF HAYMAKING

Haymaking was referred to more than 2000 years ago by Columella, a Roman agricultural writer. Progress in developing forage harvesting technology since then was relatively slow. It is only within the last 130 years or so that the scythe and pitch fork have been gradually replaced with more efficient and less labor intensive methods. The mechanical hay loader was developed in 1874 and the side delivery rake in 1893. Despite some improvements in equipment and methods over recent decades, notably the development of the automatic pick-up baler in 1940, it has been largely in the past 20 years that a revolution in forage harvesting techniques has really gotten underway.

It is interesting to read about hay making systems in use at the Central Experimental Farm in Ottava in a publication dated 1949. Hay was cut using the 1.8 to 2.1 m (6-7') horse-powered or tractor-mounted reciprocating movers and while the square and small round bales were used, most of the information dealt with methods for putting up long hay in stacks, using sweeps, overshot stackers, mast and boom stackers etc. Incidentally, equipment prices were modest (a "six foot" horse-drawn mover-$130; pick-up baler-$1200; twine-not included; a forage harvester-$1000, etc.) and labor was valued at $0.45/hour.

The magnitude of the revolution is illustrated by a statement by Hiram Droche of Concordia College who, in the mid 1970's stated that "In 1870 it took 35 hours of labor to produce a ton of hay. In 1915 using horse-drawn equipment, it took 9 hours to get the job done. In 1973, a North Dakota farmer was producing a ton of hay in only 15 minutes using stackers." We can update his comments by adding that it is now possible, using a large model round baler (Vermeer 706) to put up 24 tonnes of hay per hour (average 13.5 tonnes/hr).

A few decades ago a farm family could physically put up enough hay of adequate quality to meet the needs of small numbers of stock, producing at a reasonable level. The full potential of forage crops was not recognized. As labor supply became more critical, as herds increased in size and productivity, and as it became necessary to harvest larger areas of forages within rather critical time limits, if good quality forage was to be obtained, it became imperative that better forage harvesting systems be devised.

Perhaps also, the growing awareness of the beneficial role of forage crops in the proper management of agricultural soils resulted in forage being produced on many "non-livestock" farms and led to the need for a system(s) of forage harvesting that would result in a readily marketable product. The development of the standard hay baler and considerable auxiliary equipment to handle bales, met this need up until about 1970, when it was estimated that 80% of Canada's hay crop was put up with the standard "square" baler.

Within the last 15 years or so, the round baler has become very popular and by the late 1980's has replaced the square baler as the machine of choice by commercial hay producers and beef cattle producers.

New developments continue to take place to improve hay quality to reduce handling and storage losses and to reduce labor requirements.

WHAT'S HAPPENING IN THE FIELD?

A recent survey in Saskatchevan* found that most hay producers crop only 80-100 ha (240-245 ac). Only 6% operated on more than a section of land.

Alfalfa is by far the most popular crop, with bromegrass a distant second and followed in order by slough grass, prairie hay, clover, crested wheatgrass, cereal hays and timothy.

Most commercial hay producers take two cuts of hay while dairy and beef producers average 1.5 and 1.2 cuts annually, respectively. About 60% of commercial hay producers and dairy producers take their first cut during the last half of June, while most beef producers (57%) wait until the first half of July.

The large round bale is the choice of commercial producers and beef producers (70%) while the dairymen prefer the standard square bale (60%). Thirteen percent of dairymen and one percent of beef producers indicated that they put up their forage in the form of silage.

Average yields were estimated at 2.4 and 3.9 tonnes/ha under dryland and irrigated conditions respectively.

CHOOSING A FORAGE HARVESTING SYSTEM

Because forage harvesting equipment is expensive, labor is scarce or high-priced and the margin for profit on forage-livestock operations (like any other agricultural production system) is continually narrowing, it is

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*Hay Certification Questionnaire - Tanka Research Group, for Saskatchevan Forage Council

especially imperative that the farmer give serious consideration to the selection of a forage harvesting system that will most effectively meet his particular requirements. What factors must be considered in making this choice?

HOW MUCH FORAGE HAS TO BE HARVESTED ANNUALLY?

Engineers have determined that unless the producer is harvesting at least 200 tonnes of forage, the investment in equipment cannot be justified. In such a situation the harvesting should be "contracted out" or cooperative arrangements made with neighbors, it feasible. The main problem under these arrangements is that the crop may not be harvested at the stage of maturity desired. If the quantity of forage to be harvested justifies the investment in a forage harvesting system, the following factors need to be considered.

WHAT KIND OF FORAGE CROPS CAN BE GROWN MOST ECONOMICALLY ON THE LAND AVAILABLE?

Some crops are much better harvested under some systems than others. For example, it is often difficult to field dry sweet clover to 20% moisture for standard baling, without losing considerable feeding value due to the shattering of leaf and flower material. It is better put up in the form of silage. Grass hays such as brome or wheatgrasses both shed or dissipate moisture well in the form of large round bales, while alfalfa and other coarser-textured forages weather much less well in the unsheltered round bale. Alfalfa or other high quality legumes are required to justify the investment in hay drying systems.

HOW IMPORTANT IS HAY QUALITY?

Will the forage be fed as the main ration component for wintering beef cows or heifers, processed and fed to finishing steers, or used as a supplement along with straw for wintering cows? Will it be sold to a dairy farmer? The answer will determine not only the quality of the product required but the type of package. In some cases a system capable of handling a large quantity of relatively low quality hay (stacking wagons or round bales stored outside) or bulky silage would be appropriate. In others, the requirement for smaller quantities of high quality forage (hay drying systems or round or standard bales protected from the weather) would be required.

HOW WILL THE FORAGE BE FED?

Will forage be full-fed, or will it be fed in limited quantities on a daily basis? Will it be processed and mixed with other ingredients to formulate complete rations or perhaps chopped and fed free choice? The standard square bale facilitates the feeding of limited amounts of hay,

particularly for smaller groups of cattle. It can be easily put through a grinder-mixer. Round bales, if processed, normally go through a tub-grinder and the product cannot be mixed into uniform rations because of the larger and more variable particle size of the product. Will cattle have access to a bunker silo through a feeding gate, or will the silage have to be hauled daily to the cattle? The right choice of harvesting equipment can facilitate the feeding operation.

HOW MUCH LABOR IS AVAILABLE?

A farmer with several husky sons (or daughters) willing to work on the farm, has much more flexibility in the choice of harvesting systems than if he/she is operating alone. It is theoretically possible for a lone farmer to operate the swather, round baler and the tractor with front-end loader. It is impossible for him to carry out a silage operation! Similarly, a lone operator could carry out a harvesting system using stacking wagons with stacks deposited in the hay field for later moving to the feeding area. He would have much greater difficulty with a standard bale system. Of course, he would have trouble keeping ahead of a rapidly maturing crop with any system and quality of the product would be quite variable, but growing several crops with differing maturity dates could reduce this problem.

WHAT FLEXIBILITY IS REQUIRED?

Will there be variations in the type or amount of forage to be harvested from year to year? Almost all kinds of crops can be put up as silage, not all are suitable for round or square baling. If there is variability in the amount of silage put up from year to year, would it be better to put "surplus" silage up in plastic tubes or pile silos rather than construct another concrete-stave silo? Most livestock producers put up considerable straw for bedding and this operation can be carried out with the same equipment that is used to put up forage in some systems (round and square bale systems, stacking wagon systems, large square bale systems) but not others (silage systems).

HOW MUCH FORAGE HAS TO BE HARVESTED AND WITHIN WHAT TIME FRAME?

The number and size of various components of the harvesting system should be carefully worked out to assure the minimum capacity to do the job in the time available. That time will depend on the normal weather conditions prevailing in the area. If two or three days of good weather in a row are about all that can be expected, it is more important to bring the crop in quickly than is the case where significant rainfall is less likely. Other factors such as the distance the forage must be hauled from field to storage area, the need to move silage quickly into storage and the range in the optimum harvesting dates for different crops being harvested will all have a bearing on the size and number of various units in the system, to

permit timely harvesting. Inadequate harvesting capacity can lead to deterioration in hay quality either due to overmaturing of the crop or to excessive weathering between cutting and packaging/storing.

WHAT KIND OF WEATHER CONDITIONS ARE NORMALLY EXPERIENCED DURING HARVESTING AND STORAGE?

Where there is little chance of getting at least three good drying days in succession, it may be necessary to use systems that require minimal field drying (silage, hay drying systems). When considerable precipitation is likely to be experienced during the summer, fall or winter, the use of stacking wagon systems is not recommended unless special care has been exercised in properly topping the stacks. Bales stacked outside, unless specially protected, will suffer significant loss in both quality and quantity. The use of a hay shed for storing baled hay is recommended, particularly where hay quality is important, or when hay must be stored for more than one year.

WHAT INVESTMENT WILL BE REQUIRED AND WHAT IS THE COST PER YEAR AND PER UNIT OF FORAGE?

High equipment costs, coupled with high interest rates, can be very risky in the beef cattle business, where the value of the product varies much more widely than in the dairy business.

High cost systems, such as the oxygen-limiting, glass-lined silo, or the hay drying tower have to be justified on the basis of cost per unit of dry matter stored, and the quality of the product. In the Aspen Parkbelt silos are normally filled once a year. The high-priced, bottom unloading silo may be justified in other areas when it can be continuously filled over a long harvesting season or where the product is fed to high producing dairy cattle. The hay drying tower, while permitting the rapid harvesting of high quality legume hays, should be managed in such a way that it is filled at least twice each summer, and the product used to supplement low cost rations for wintering beef cows, rations for rapidly growing feedlot cattle or to supply foreign markets with the low-fibre, high-protein hay that brings top market price.

If high cost equipment can be maintained at reasonable cost in relation to that of lower cost systems over many years, the investment may well be justified. However, most beef producers are not in a position to make large investments in equipment and prefer to purchase standard or round balers for haying and to use a multi crop swather-windrower, a forage harvester and bunker, pit or pile type silos when putting up silage. It is also important that good service be available to maintain equipment in the event of a breakdown. Generally speaking this is more likely to be readily available for the more popular (lower priced) equipment.

WHAT FACILITIES AND EQUIPMENT, IF ANY, ARE CURRENTLY AVAILABLE?

Where logical, when changing from one system to another, the operator should consider how the new system will fit in with the existing facilities. Some systems have certain equipment in common - silage and hay tower systems both use forage wagons, a forage harvester and possibly a blower. A grinder-mixer will handle standard bales or chopped hay conveyed from a hay drying tower. Unfortunately, there is no economical means, as yet, of processing round bales through a standard grinder-mixer. Hay racks can handle standard or round bales. Feedlot facilities, self-feeders, bunks, etc. may be designed to fit one forage system and not another.

IS IT PLANNED TO SELL FORAGE?

If selling hay, the standard and round bales are the packages of choice when shipping long distances. Silage, on the other hand, unless put up originally in plastic containers (1 tonne units for example) is subject to spoilage and freezing once removed from conventional silos. In any case, shipping cost per unit of nutrient is high due to the high moisture content. Dried, chopped hay would have to be especially baled or packaged to prevent loss of fine material and to reduce bulk during shipping. Weights and densities of harvested forages are shown in Table 1.

Table 1 Estimated Densities of Harvested Forages*

	Weight Range		Density	
	kg	(pounds)	kg/m³	(lb/cu. ft)
Standard bales	23-27	(50-60)	144-208	(9-13)
Large square bales	550-860	(1200-1900)	95-160	(6-10)
Large round bales	500-1400	(1100-3100)	144-208	(9-13)
Stacking wagons				
-compression type	700-9500	(1600-21000)	75-95	(4.6-6.0)
-non-compression type	3600-6000	(8000-13000)	50-67	(3.2-4.2)
Silage (40% D.M.)	n/a	n/a	65-105	(4.0-6.5)

*Guide only, actual densities will vary with the type and moisture content of the forage, size of cut (silages) and the make and size of the equipment.

FORAGE HARVESTING LOSSES

Apart from the major nutrient (quality) losses that occur when forages are harvested after reaching their optimum stage of maturity (see companion publication "Utilization of Harvested Forages in the Aspen Parklands of Western Canada") there can be very significant losses during the harvesting and storage operations. While losses occurring in specific systems, and how

they can be minimized, will be covered in the sections dealing with the specific system, some general comments on factors affecting losses are as follows.

MOISTURE CONTENT AT HARVESTING

Harvesting hay with less than 20% moisture will lead to increased loss of leaf and flower material (the most nutritious parts of the plant). Harvesting at greater than 20-30% (depending on the crop and the haying system) can lead to increased spoilage during storage, if bales or stacks do not undergo further drying within a few days.

Silage moisture levels should be between 60-70% (may be lower for oxygen-limiting system). Drier silage will be more difficult to pack and could suffer greater field losses when chopped. Wetter silage will be more difficult to properly ensile, have lower feeding value (due to its bulk) and may suffer losses due to seepage.

Optimal Moisture Content at Harvesting* (%)

Standard Bales	20-25
Round Bales	
- hard core	20-25
- soft core	20-30
Stacking Wagons	
- non-compression stacking wagons	25-30
- compression type stacking wagons	25-30
Silage	
- pile, pit, bunker, bag	65-70
- oxygen-limiting systems	55-60
Hay Drying Systems	35-40

*Will vary with the kind of hay (grass vs legume, weather (drying) conditions, length of cut (silage), hay yield (time to form bales) and amount (rate) of settling in stacks.

CUTTING AND RAKING PRACTICES

Ideally, the hay or silage crop should be cut, conditioned (legume crop) and windrowed in one operation, using either a swather, conditioner, windrover or a mover-conditioner-windrover. Raking swathed hay with a moisture content below 35-40% (depending on the type of crop) can lead to serious losses (up to 25% for legumes) in quantity and quality.

YIELD OF CROP

Higher yielding crops will produce the larger windrows required, not only for more efficient equipment operation, but to reduce the loss of fine material due to a reduction in "processing" time within the baler or forage harvester. Double windroving, or raking two windrows into one, may reduce losses provided the combining of windrows is done at a moisture content above 40-50% and at a reasonable speed. For silage operations, where time is important, large windrows mean shorter time between field chopping and putting the material into the silo, thus reducing oxidation. A harvesting rate of between 4 and 7 tonnes of hay equivalent per hour (70 kw or 95 HP tractor) should be maintained if possible.

EFFICIENT OPERATION OF EQUIPMENT

Proper maintenance and adjustment of the equipment is essential to efficient operation and to minimize "down time" due to equipment failure. Careless operation of equipment can result in incomplete pickup of the crop, loss of material by misdirecting the spout on the forage harvester, or stacking wagon, overfilling of stacking wagons and plugging of blowers. Losses can occur when stacks are not properly unloaded or when improperly settled stacks are deposited in unprotected areas during high winds. It requires considerable operator skill to put a good top on stacks formed by mechanical stacking wagons. Poorly shaped tops lead to penetration of the stacks by rain or melting snow, which causes spoilage (losses vary with the kind of hay and the amount of precipitation, but are estimated at 5-15%). In many cases spoilage could be reduced by manually "topping off" the stacks.

LOCATION AND STORAGE

Bales, stacks, and pit, bunker and plastic bag silos should be placed on a well-drained site to prevent contamination and spoilage by absorbed surface water. Bale and long hay stacks should normally run north and south to allow maximum access to the sun and prevailing winds to dry out stacks. Round bales should, ideally, be placed in single rows with butts touching, but not sides touching. For convenience, however, round bales are usually stacked in a 3-2-1 row "pyramidal" pattern or may be piled one or two on end with one bale laid on its side, on top. The latter configuration is a good compromise between efficient use of space and protection from the weather. Square bale stacks should be straight-sided and be as high as possible (12-16 layers) to minimize the percentage of spoilage. Topping of such stacks with rows of straw bales across the width of the stack, spaced so that the distance, center-to-center of the rows is equal to the length of the bales, and placing a solid layer of straw bales running parallel to the length of the stack, on top, will absorb most of the precipitation and permit the top row to dry our between rains, thus protecting the more valuable hay underneath.
Alternately, the top of the stack can be covered with plastic sheeting, held down by a row of bales or with twine or netting. It is not a good idea to

cover more than the top row of bales with an air-tight cover, as this will tend to trap moisture and cause spoilage, particularly if the hay contains more than 15-20% moisture.

Pile, bunker and pit silos should be covered with plastic, sealed with sand, gravel, earth or manure around the base or edge of the plastic, and held firmly in place with old tires, twine or netting. Covering with a layer of tightly placed straw bales will prevent or reduce losses due to freezing in the winter normally experienced in the Aspen Parkbelt. Plastic covering should be protected from puncturing.

In an ideal situation hay bales should be stored under a roof. Investment in a shelter is likely to justify itself particularly if hay has to be stored for more than a year, if hay is of good quality, and if the price for hay is good.

The use of preservatives in hay making is covered in another section of this publication.

Estimated average losses for various forage harvesting systems are shown in Table 2. Under excellent management, losses will be less, but, on the other hand, hay has been totally lost by severe or lengthy weathering or spoilage.

Table 2 Estimated Average Losses for Various Forage Harvesting Systems* (%)

System	Moisture (%)	In field prior to harvesting	Harvesting	Storage	Feeding	Total
Pile silo	65	2	1-2	15-20	5	23-29
Pit silo	65	2	1-2	15	4	22-23
Bunker silo	65	2	1-2	10-20	4	18-28
Concrete stave tower	65	2	1-2	8-9	2	13-15
Oxygen limiting	45	2	1-2	4	2	9-10
Silage tubes	65	2	1-2	5-9	4	12-17
Round bale silage	65	2	2-3	10-25	4	19-34
Standard bales (shelter)	20	3-4	4-6	2	5	14-17
Round bales (outside)	25	3-4	3-5	6-8	6	18-23
Stacking wagon -compression	25	3-4	3-8	5-10	5-6	16-28
-non-compression	25-30	3-4	4-10	10-18	5-6	22-38
Hay drying	30-40	3	2-3	3	3	10-12

*Actual losses will vary with skill of operator, weathering conditions in the field (moisture, sunlight, wind), yield and kind of crop, quality of storage techniques and care in handling feed and design of feeders.

CUTTING CROPS FOR HAY

The moving to windrow operation, with or without conditioning (crimping or crushing) is very important, as it can affect the rate of drying, yield and quality of hay at the time of baling, stacking or field chopping, and the extent of quality loss during these operations. A reduction of drying time of even a few hours can markedly reduce losses due to respiration of the plant and to weathering.

There are a number of options available when deciding on how the crop shall be cut and swathed.

1. Conventional pull-type or tractor mounted mower with reciprocating sickle bar [usually 1.8 to 2.2 m (6-7')], followed by a side delivery rake. (This method is well suited to low-yielding crops (i.e. native hay) on rough terrain.)

2. Mower-conditioner with deflectors removed, to leave conditioned hay in a full-width swath, followed by raking.

3. Mower-conditioner set to leave conditioned hay in a windrow, eliminating the need for raking.

4. Self-propelled swather-conditioner, in which the windrow is formed and then processed through the crimper or crusher.

5. Other machines have been developed, such as the drum mower, which has two or four rotating discs with free swinging blades attached, and which leaves the hay in one or two swaths respectively. This mower can cut hay faster, but is not in common use.

Methods 1 to 4 have been evaluated at Melfort over several years. Drying rate was slowest with Method 4. While eliminating the need for raking, the possibility for exposure to weathering would be increased.

Forage cut with the mower-conditioner and swathed, not windrowed (Method 2) tended to dry more quickly than in the other methods and could thus be baled sooner. It is important that conditioned hay be baled as soon as it is dry, otherwise it runs the risk of absorbing precipitation quickly, due to the breaks in the stems.

Under Methods 2 and 4, neither forward speed (5 to 11 km/hr), or width of cut (3.2 or 4.9 m, 10 1/2 - 16') affected drying rate. In Method 4 there was little difference in drying rate between crimped or crushed hay.

When yields are heavy, narrower cuts, logically, will produce lighter, faster-drying windrows. When yields are light, windrows may need to be combined to achieve efficient baling, stacking and field chopping operations. Side delivery rakes are available which combine two swaths into one windrow.

RAKING

Method 2, although promoting faster drying, requires a raking operation, which increases operation costs and causes more leaf loss than under Methods 3 and 4.

Raking losses of 25% are not uncommon. Losses can be reduced by raking at 40% moisture or higher and by reducing speed. Raking losses are higher for legumes than for grasses and lower for native grasses than tame grasses.

An experiment was conducted to determine the feeding value of bromegrass- alfalfa and sweetclover hays harvested using four cutting systems:

1) mower and rake (MR),
2) mower-conditioner swather (MCS),
3) mower-conditioner- windrower (MCW),
4) self-propelled conditioner-swather (SP).

All hay was baled at 20% moisture and placed in a shelter. Hay cut with the mower-conditioner-windrower was handled three ways:

1) placed into a shelter immediately following baling,
2) stored in stooks,
3) single bales were left in the field for four weeks and then placed in a shelter.

Weather conditions were quite good from cutting to baling [0.25 cm, (0.1")] while hay stored outside received 14.2 cm (5.6") of rain in 13 showers. Each of the hays was fed to seven, individually-stalled growing finishing lambs, fed once daily all the hay they could consume. Water and cobalt-iodized salt were available free choice. The effect of cutting method on hay quality and on lamb performance is summarized in Table 3.

COMMENTS

1. While dry matter digestibility was higher for both hays, when raking was not required, this difference in feeding value was not translated into higher yields of lamb per tonne of hay consumed, except for the lambs fed the brome-alfalfa which was windroved using a self-propelled swather.

2. Exposing single bales to weathering in the field for four weeks markedly reduced the feeding value of both hays, while storage under a roof was much more important for the sweetclover hay than for the brome-alfalfa hay, which stored well in the field, in the form of stooks.

3. In practice, much will depend on the weather conditions experienced during the harvesting period. In this test, conditions were good from cutting to baling and conditioned hay was placed into shelter with minimal

Table 3 Effect of Harvesting and Storage Treatments on the Performance of Groving Lambs (1 year trial)

	Moving Treatment				Storage Treatment		
	Mov & rake	Mov condition swath rake	Mov condition windrov	S.P. swath windrover	Shelter	Stook	Single bales
Brome-Alfalfa							
Average initial wt. (kg)	27.8	28.0	27.8	28.0	27.8	28.5	28.6
Average daily gain (gm)	123	132	141	168	141	141	104
Average daily dry matter eaten (g)	985	917	994	1075	994	1012	881
Feed:gain ratio	8.86	8.29	8.55	7.16	8.55	8.04	10.21
Dry matter digestibility (%)	58	58	60	63	60	60	58
Crude protein (%)	14.4	14.8	14.8	15.5	14.9	14.5	13.8
Lamb gain/tonne (kg)	113	121	117	140	117	124	98
Sweetclover							
Average initial wt. (kg)	28.0	28.0	27.8	28.0	27.8	28.4	27.6
Average daily gain (gm)	132	150	159	150	159	109	123
Average daily dry matter eaten (g)	926	1008	1062	1003	1062	850	872
Feed:gain ratio	7.44	8.22	7.34	7.34	7.34	8.82	10.79
Dry matter digestibility (%)	57	58	59	62	59	53	54
Crude protein (%)	13.3	12.8	13.2	14.7	13.2	13.8	14.1
Lamb gain/tonne (kg)	134	121	136	136	136	113	93

exposure to rain. Under more adverse weather conditions results could be quite different, likely causing more marked differences in feeding value than occurred in this test.

4. When the hays were fed as 70% of the ration along with grain and a mineral-vitamin-antibiotic supplement, the differences in the feeding value of the hays were eliminated. It is also noteworthy that the hays in this test were ground through a 6.3 mm (1/4") screen, which would also tend to reduce the differences in feeding value of the hays.

EFFECT OF SWATH SIZE ON YIELD AND QUALITY OF HAY

A bromegrass-alfalfa stand yielding 5064 kg/ha was cut with a 2.8 m (9') mower conditioner and left in the swath. A parallel bar side delivery rake was used to form windrows from the 2.8 and 5.6 m wide swaths. The hay was put up with a McKee stacking wagon and fed the following winter to two groups of 27 yearling Hereford heifers which also were fed dry rolled barley at the rate of 0.9 kg/head/day. The condensed results are in Table 4.

Table 4 Effect of Double Windrowing on Yield and Quality of Hay Harvested

Windrow	DM* (kg) Into storage	DM* (kg) Out of storage	DM loss (%)	Average daily gain of heifers (kg)	Fed/ unit gain	Gain/ ha (kg)
Single	1853	1459	21.3	0.46	16.4	235
Double	1807	1411	21.9	0.45	15.8	238

*DM = Dry Matter

COMMENT

No advantage to double windrows from a feed quality standpoint, but obviously more efficient to harvest (bale, stack, etc.). (Raking is not desirable in any event.)

ESTIMATION OF MOISTURE CONTENT OF FORAGES USING THE MICROWAVE OVEN

The moisture content of forage can be quickly estimated by using a microwave oven and a sensitive scale. The procedure is as follows:

1. Make a tray about 8 cm high using the bottom of a large Kraft-type paper bag.

2. Place 100 g (exactly) of the forage sample, cut to 7 cm lengths, into the tray.

3. Put the tray, with sample, in the microwave oven, allowing space under the tray for air movement.

4. Dry the sample for 4 minutes at high heat, remove and stir to cool. Weigh.

5. Dry another 2 minutes, remove and stir to cool. Weigh.

6. Repeat 5., if the sample is still losing weight.

7. The weight of the dried sample (in grams) is the % dry matter, if a 100 gram sample was used. Otherwise, divide the weight of the dried sample by the initial weight and multiply by 100.

Note:

a. The principle is to quick-dry the sample to a constant weight. The procedure can be varied somewhat.

b. The paper tray will lose some weight as well. If the sample and the paper tray are weighed together, the weight change of the paper tray should be taken into account.

c. The glass tray in the oven is designed to prevent overloading of the magnatron. Using a glass of water in the oven will have the same effect but tends to increase humidity in the oven or even cause condensation which hinders the drying process.

d. Stirring the sample is to prevent local overheating which might ignite and cause fire. It is advisable to remain at hand during drying.

HARVESTING CROPS FOR SILAGE

WHAT IS SILAGE?

Silage is made from agricultural crops (i.e. edible by ruminant livestock) which are finely chopped, compressed to exclude air and preserved by acids created by fermentation in an air-tight container (silo).

The ensiling process

1. Aerobic stage (several hours to several weeks - minimize by fine chopping, thorough packing and excluding oxygen)

Plant material → Carbohydrates (-sugar, -starch) + Oxygen ---(plant enzymes (respiration); micro organisms)---> Carbon dioxide and heat

2. Anaerobic stage (3-4 weeks)

a) Plant material + ---(lactobacillus; anaerobic bacteria)---> lactic acid - lower pH to 3.5-4.5 (inhibits microbial activity)

b) Carbohydrate, lactic acid and protein + ---(clostridial bacteria)---> butyric acid

The relative proportion of these reactions determines silage quality. Good silage has the typical silage smell, poor silage has the rancid odor of butyric acid. While these reactions predominate, many other microorganisms (yeasts, molds, bacteria) are utilizing plant nutrients to produce a host of compounds by breaking down protein and sugars.

Silage systems (General)

Successful silage making involves several basic steps prior to and following placing the material into the silo itself. These are summarized as follows.

1. Determining the optimum stage of maturity of the crop, in order to achieve the yield and quality desired. The feeding value of perennial grasses and legumes declines with advancing maturity, yield increases to about the early heading or flowering stage and then declines. With cereals and corn, optimum yield and quality for silage making is at the dough to firm dough stage for cereals and the hard dough stage (60-70% moisture) for corn. (In much of the Aspen Parkland corn must by left until late in the fall in order to reach an optimum moisture level.)

2. Cutting and windroving, using a swather (conditioner optional, but may speed wilting of legumes) or mower-conditioner. Cereal crops may be dry enough to harvest directly with the forage harvester while corn is normally harvested directly. For round bale silage, the crop is harvested with a round baler (using rollers, not belts) and smaller bales (due to their greater densities) are formed.

3. Determining when the optimum moisture content for the system involved, is reached. [Pile, pit and bunker silos - 60-70%; concrete stave silos - 60-65%; and oxygen limiting, metal or glass-line metal silos, and plastic bag (tube) silos - 40-50%.]

4. Picking up the windrow or standing crop with a forage harvester set to finely chop the crop into 5-12 mm (0.25-0.50") lengths. If stems in the windrow are not parallel to the swath, a recutter screen may be required to produce uniform, short-cut material. Optimum length of cut will vary with the physical nature of the plant material and the moisture content at ensiling. Material that is at less than optimum moisture must be more finely cut than material above optimum moisture level, in order to facilitate good packing. Grass silage should be chopped more finely than corn silage.

5. Moving the chopped material rapidly (by forage wagon, high dump wagon, or dump trucks) to the silo to minimize exposure to air.

6. Getting the material into the silo as quickly as possible with minimal exposure to air.

7. Thoroughly packing the silage (except for upright silos where the weight of the silage does the packing).

8. Covering the silage (except for upright silos) as soon as possible with any material (usually plastic polyethylene sheeting) that will exclude air and anchoring the cover with tires, netting, etc.

9. In most of the Aspen Parkbelt it is usually necessary to insulate pile, bunker, or plastic bag silos with a row of straw bales, or other insulating material, to reduce freezing. Otherwise considerable silage can be wasted.

ADVANTAGES AND DISADVANTAGES OF SILAGE SYSTEMS (GENERAL)

Advantages

1. Silage can be made from almost any crop, many of which cannot be conveniently harvested, or are harvested with difficulty by other methods (cereals, sweet clover, corn, faba beans, weedy crops that may be hard to field cure).

2. Silage can be put up under unfavorable weather conditions (little or no field drying required) which minimizes harvesting losses, thus permitting maximum nutrient yield per unit of land.

3. If properly timed, the silage operation will remove weeds prior to seed shedding and thus help to reduce weed infestations, particularly in newly-seeded forage stands and in annual crops.

4. Removing an annual crop, (such as oats, which has been underseeded to winter wheat or fall rye) as silage, results in minimal damage to the underseeded crop compared to some other harvesting methods.

5. May be stored for many years if properly sealed.

Disadvantages

1. Most silage systems require more labor and time per unit of dry matter harvested, than do other systems.

2. Once cut and field-wilted to the optimum stage of maturity for the silage system involved, the crop must be field-chopped and moved quickly into the silo to assure uniformity of feeding value and to minimize spoilage losses.

3. Silage is bulky and contains a lot of water (60 to 75%) hence is costly to transport from field to silo. Unless put up in sealed packages (1 tonne packages are now being produced in some areas to facilitate marketing) transporting silage out of the silo to a market at any distance is not feasible.

4. Because silage is bulky, its use in rations for high-producing livestock is limited, as it must be supplemented with some dry feed, grain or hay, to allow adequate nutrient intake. It cannot be processed to reduce its bulk and thus increase intake (as hay can be). The only option to improve animal performance is to supplement it with other higher energy, lower bulk feeds.

5. The odor of silage is offensive to many people.

6. Silage operations require a lot of energy to fine chop, transport, convey, pack or blow and to unload and feed to livestock (Table 5).

7. During cold weather, silage often freezes, making removal from the silo difficult, particularly in the case of tower silos.

8. Normal wastage in silage systems varies from 20-30%, most of it during the storage phase, due to spoilage and freezing.

Table 5 Energy Requirements of the Silage System

Operation	Power Source*	Implement	Energy Consumption L/t	L/hr	kwH/t DM	Work Rate t/hr
Field Chopping						
Barley 45% M** (3.2 mm screen)	IHC 1066 (D)	New Holland 718	2.4	25.1	-	10.4
Alfalfa 60% M (3.2 mm screen)	IHC 1066 (D)	John Deere	4.3	16.7	-	4.0
Hauling	IHC 706 (G)	Badger wagon	0.4/km	-	-	-
	IHC 684 (D)	Badger wagon	0.2/km	-	-	-
Conveying	M.F. 165 (G)	John Deere flight conveyer	0.3	-	-	-
Packing	Clark 35C (D)	-	6.6	2.9	-	-
Filling Tower Silo	IHC 684 (D)	Badger blover	1.4	9.7	-	7.2
	IHC 1066 (D)	Badger blover	2.7	15.7	-	5.8
	22.5 kv (E)	New Holland 27	-	-	2.5	-
	0.56 kv (E)	Even-flo distributor	-	-	0.6	-
Tower Silo Unloading						
Cold winter	5.6 kv (E)	Clay unloader				
	0.6 kv (E)	vinch			4.9	
	0.8 kv (E)	conveyer				
Mild winter	5.6 kv (E)	Clay unloader				
	0.6 kv (E)	vinch			2.9	4.8
	0.8 kv (E)	conveyer				

*D - diesel; G - gas; E - electric motor
**M - moisture

Source: Dr. E.Z. Jan

SILAGE PRESERVATIVES AND ADDITIVES

When proper procedures are followed, there is no advantage in adding preservatives to silage and the procedure will be a vaste of time and money. When silage must be brought in at higher than optimum moisture levels, it may be advantageous to use some types of preservative to improve the ensiling process and thus the feeding value of the silage. Many products are on the market but, in most cases, results of using them are variable and

unpredictable. The silage producer is advised to check out claims made by those selling such products to be sure that the product has been tested by a reputable research organization and that the claims represent the facts.

Several feeds can be added to wet silage to reduce the moisture content, perhaps the most effective means of improving the ensiling process. Adding ground cereal grain will reduce the moisture level (80 kg/tonne of wet silage will reduce the moisture content by about 5%). The grain provides soluble carbohydrates which may, under some conditions, increase acid production and speed the preservation process. The grain itself is reduced in feeding value due to fermentation losses, but if its use salvages the silage, it could be justified. Adding dry, ground, high quality hay has also been used to reduce the moisture content. (Straw could be used, but would add nothing to the feeding value of the silage.)

Mineral (hydrochloric, sulfuric and phosphorous) acids and organic acids (propionic and formic acids) have been used to preserve high moisture silage but are corrosive and must be used with caution. Of these, a "neutralized" propionic acid product is probably the most promising.

Bacterial and mold inhibitors are on the market but the levels required for effective results are economically prohibitive.

In some situations, it may be convenient to correct nutritional deficiencies in the silage by adding appropriate compounds. Adding urea to corn silage will increase the crude protein level at the expense of the energy level, providing a better protein to energy level more closely meeting the requirements of some classes of ruminant livestock. Limestone (calcium carbonate) has also been added (0.5-1.0%) to corn silage to favor the activity of the lactic acid forming bacteria and to improve the calcium:phosphorous ratio of the silage.

In summary, it is better to use proper ensiling techniques than to attempt to correct mistakes by the use of additives. Where conditions, or errors, have created problems, some additives will, or may, work under some conditions. Be sure to use only properly evaluated additives and to use them as directed by the manufacturer. Adding ground grain may be the best method to use, considering cost, safety and the ability to reduce moisture content.

There are many systems used for putting up silage. The following is a brief description of some of the more popular systems and an assessment of their special merits or disadvantages.

PILE TYPE SILO

Silage is simply dumped on the ground (well-drained site), pushed into a wedge-shaped stack, packed and covered with plastic (6 mil polyethylene) sheeting, starting from the high end of the wedge as the desired height is reached and the stack top is leveled. If interrupted, the plastic is pulled

over the remaining portion of the stack and held in place with tires, netting, etc.. When the pile is completed and sealed, it is normally covered with a layer of straw bales to prevent wind damage to the plastic sheeting and to insulate the silage during cold weather. This system is low cost but does lead to greater losses due to spoilage along the sides, which are difficult to safely pack. There is also a greater problem in "cleanly" picking up the silage when removing it with a front-end loader.

BUNKER TYPE SILO

Silage is placed between movable, or permanently fixed walls made of concrete, plywood or treated tongue-and-groove lumber and placed on a concrete or paved base. Walls are normally 2.5-3.7 m (8-12') high, sloped outward at the top by about 8° off vertical, to facilitate packing. Width and height can vary to meet requirements, but the greater these dimensions, particularly the height, the less will be the spoilage and freezing losses as a percentage of the total. If planning to self-feed from the silo face, height will need to be limited to the reach of the cattle [1.8-2.8 m (6-8')] and width must not be so great that cattle cannot remove at least 10 cm (4") of material daily (to reduce exposure to air, and spoilage). For best results place plastic sheeting on the inside walls with enough extending to lap the top sheet by about 1 m (3'). If the silo is made with treated lumber, the plastic sheet must be used to prevent possibility of poisoning the cattle, through contamination of the silage with the lumber preservatives used.

Filling is best done by dumping the silage at one (or both ends if the silo is very long) and pushing the silage up to desired height at the end (or middle) and then building along the slope of the ramp to the end(s). If end unloading wagons or dump trucks are used they can back into the silo to discharge the silage, saving time in pushing the silage into place with the front-end loader. As the silage reaches the desired height and is packed, the plastic cover is pulled over the silage, lapped over the side sheets, held in place, and gradually extended over the silo as it is being filled. When filling and packing is completed, anchor the cover and insulate with straw bales.

Compared to the pile type silo, this unit obviously costs more, but is easier to pack and easier to feed from, which tends to reduce wastage.

TRENCH SILOS

Trench silos are cut into the side of a hill to allow ground-level access and proper drainage. Walls should be sloped (1:2) to prevent caving in (select clay vs gravel or sand, if possible, or cover unstable soil with untreated lumber). Suggested width (to facilitate loading) is 15 m (50'). It is also advisable, especially if self-feeding from the silo, to install a

reinforced, acid-resistant, concrete floor, with a 1-2% slope down to the open end (facing south). The top of the silo should be covered to exclude air. Because it is largely underground, freezing losses should be less than for pile or bunker silos.

Density of silage in horizontal silos varies from 468 to 635 kg/m^3 (30-40 lb/ft^3) depending on silo depth, 2.5 to 4.9 m (8-16').

ROUND BALE "SILAGE" SYSTEM

With the growing popularity of the large round hay bales, came the possibility of putting up high-moisture (65%) hay and conserving it as "silage", either by placing the bales into plastic storage tubes or bags or by piling the bales in a "pyramidal" row in a 3-2-1 configuration and sealing the "stack" with 6 mil black plastic sheeting held to the ground at the edge of the stack with sand. The cost of the plastic sheeting is about $3/tonne of forage stored. The diameter of bale is reduced to lessen stress on the baler and other handling equipment due to the heavier weight of forage per unit volume. This means that smaller diameter plastic bags can be used than is the case when storing chopped silage. A hard-core, slatted-chain baler has given good results at Melfort. Belt-type balers become slippery after making a few bales.

Several types of baggers are available. One is a 1.4 m (4.5') diameter silage bagger which will handle a 1.2 m (4') diameter bale. A front-end loader deposits the bale onto a slide. A tractor-powered hydraulic ram pushes the bale off the slide and into the drum. The bale is forced out of the drum into the bag by the next bale. The unit costs about $6000. It takes two people 20 to 30 minutes to attach the 23 m (75') long plastic tube onto the drum. However, a prefolded tube is available at extra cost ($12-15) which can be easily attached by one person. Another bagger ("Bale Star") consists of a short drum on a stand. The bag is attached to the drum. Bales carried by a spear on a 3-point hitch mounted on a front-end loader are pushed through the drum into the bag. A chain under the bale spear catches the unit and moves it forward one bale length as each bale is added, care being taken not to touch the drum with the bale. (Cost of this unit is about $1600 and no additional tractor or person is required as in the first type of bagger described.)

The "Stirling" bagger uses the same principle but is equipped with a platform so that the tractor holds down the bagger while feeding in the bale. This bagger is available in single bale and three bale units.

Another machine called the "tubulator" is pulled by a tractor which picks up the bales, laid in a row, and drops them into a plastic tube which is carried on the machine. The tube is pulled off the bagger by the weight of the bale and the forward motion of the tractor.

The cost of the plastic tube is about $14 per tonne of dry matter stored

when using 1.2 m (4') diameter bales. While the cost could be reduced slightly by using larger (1.5 m or 5") bales, these bales at 65% moisture weigh 1520 kg (3350 lb) and will be harder on the baler. They would also require a larger front-end loader tractor.

At Melfort, exhausting the air from the tubes with a shop vacuum cleaner, right after sealing the tubes, and again the following day, has reduced temperature buildup and damage by cats claving their way up to a warm resting place. It has also reduced mold growth observed when air was not exhausted from the tube. However, in both cases the feeding value of the silage was excellent and compared favorably with similar forage put up as hay and fed to yearling beef cattle.

The "silage" had a pH of 6.5, indicating that the term "high moisture hay" would be more valid than "silage".

Feeding of high moisture round bales is more difficult than feeding large round hay bales unless cattle numbers warrant access to at least one full bale at a feeding. High moisture bales, unless consumed quickly will start to spoil, particularly in warm weather.

NEW DEVELOPMENTS

Since about 1988, equipment has been available to apply plastic wrapping to large round "above average moisture" hay bales. A unit in Saskatchewan injects individual bales with anhydrous ammonia and applies a plastic wrap. Another type of automatic wrapper for round, high-moisture bales for silage, has been introduced into Canada from Scotland. These units wrap rows of bales, "sausage style", at a rate of about one bale per minute and a cost of $2.50 per bale. More research must be done with these units to determine the feeding value of the product compared to similar forage put up under other methods.

PLASTIC BAG (TUBE) SILAGE SYSTEM

This system involves the use of plastic bags into which chopped forage (or grain) can be packed by means of a machine attached to the open end of the bag. An end frame is connected by 2 side cables, to the packing unit to maintain pressure on the tube. The bags are double walled, 2.4-2.7 m (8-9') in diameter and vary in length from about 37-40 m (120-140') A 2.7 m (9') diameter bag will hold about 3 tonnes/m (1 ton/ft) of chopped 60% moisture silage.

Bags should be located close to the feeding site, on well-drained, smooth areas for easy access by front-end loaders when transporting the silage to the feeding site. Special care is required to prevent damage to the bags by sharp objects and rodents, and punctures should be sealed (with adhesive tape) as soon as possible.

Because of their relatively large surface area per unit of feed stored, plastic tube silos are succeptible to freezing in the Aspen Parkbelt winters. Covering the tube with a layer of straw bales will reduce or eliminate freezing.

The advantages and disadvantages of this system are as follows.

Advantages

1. A relatively low cost storage system with no construction costs [Bags about $5/m ($1.50/ft)].

2. Can put up small quantities of silage at a time, with minimal exposure to air.

3. A flexible system with respect to capacity and time of filling; can supplement an existing system.

4. Small surface area is exposed during removal of silage.

5. Moisture content can vary from 70 to 55% (silage to haylage) because of the oxygen limiting feature of this system.

Disadvantages

1. The packing unit is high cost (favoring a custom operation).

2. Bags can be used only once and create disposal problems.

3. Bags are subject to puncturing (sharp objects, birds, cats clawing their way to a warm resting place).

4. Bags are reliable for short-term storage only.

5. Storage area is considerably greater than for some other silage systems.

UPRIGHT SILAGE SYSTEMS

This system involves the use of a cylindrical storage structure made of concrete staves, poured concrete, metal or glasslined metal. Precast concrete stave silos, held in place by metal hoops can be erected quickly and if properly constructed make an excellent unit. The walls should be inspected regularly for air leaks and coated to protect the concrete from corrosion by acids. Cast-in-place silos have thicker walls than the concrete stave silos and are preferred for large silos. There is less likelihood of air leakage but they should be periodically inspected for cracks. The use of acid resistant concrete and of acid resistant coatings is advised.

Oxygen-limiting silos have air-tight walls and are equipped with devices to eliminate air flow into the silo, as the silage is removed. These are normally quite expensive. Moisture content of silage should be around 40-50% to optimize dry matter capacity and assure proper fermentation. They are usually bottom unloading which permits continuous feeding, even while adding new material at the top. In the Aspen Parkbelt, with its short growing season, it is difficult to justify the investment in this type of silo as the yearly throughput is quite limited (likely one filling) compared to that possible in areas with longer growing seasons.

Silos are filled by means of a blower and unloaded with either top-unloading or bottom unloading units which convey the silage to loading chutes or directly into cattle feeders in a fully automated feeding system.

Filling rate should be adequate to match the field harvesting rate. Filling can be facilitated with feeder boxes which allow the truck or wagon to dump its full load quickly and return to the field, while the silage is fed evenly into the blower. About 0.75 kw (1 HP) is required for each 30 cm (1') of tower height.

To minimize freezing, moisture content of silage should be kept below 65% in concrete silos and below 50% in oxygen-limiting towers.

ADVANTAGES AND DISADVANTAGES OF UPRIGHT SILO SYSTEMS

Advantages

1. The system is fully mechanized.

2. Feeding system can also be automated.

3. Filling rate is not so critical as with the horizontal (bunker and stack) silos.

4. Requires little land area per unit of silage stored.

5. No packing or covering is required (silage is self packing).

6. Usually the most foolproof way of putting up high quality silage.

7. Low storage losses.

8. If bottom unloading, permits greater through put during the year as new material can be added at any time without interrupting the feeding operation.

Disadvantages

1. A relatively high capital cost for the silo, blower and distributor-unloader.

2. Silo must be well constructed (perfectly round, no air leaks) and on a good foundation (to prevent leaning or toppling); and well maintained to prevent mechanical breakdown.

3. Entering an upright silo is hazardous due to the possible presence of silo gas.

4. High moisture silage may freeze at the top and walls of the structure, creating unloading problems.

5. Requires readily available service people to handle mechanical breakdowns.

6. Breakdowns are serious as there is no alternative means of getting the feed to the livestock.

7. May have seepage losses if moisture content is too high (due to greater pressure on the lower portion of the silage).

8. If not oxygen limiting, storage losses can be high if the product is put up too dry (i.e. <55% moisture).

9. Unloading is slow compared to unloading a bunker silo with a front-end loader.

FEEDING SILAGE

Good silage, apart from its nutrient content, will have a clean, pleasing acid odor. Poor silage may have a rancid, butyric acid smell. Good silage will be properly fermented and have as high a dry matter content as possible consistent with a successful fermentation process. Color of good silage can be quite variable depending on the crop. Usually it is green, or brownish-yellow but in the case of faba bean, for example, it is very dark which, for other crops, would indicate rotten material. It should be free of foreign material, with no visible mold, mustiness or sliminess. The ultimate, and only real criterion of silage quality is its palatability or acceptance by livestock, allowing for an initial adjustment period during which cattle sometimes show some reluctance to consume silage.

Because of its bulky nature and tendency to spoil quickly when exposed to air, silage is normally fed once or twice daily in limited amounts to most classes of livestock. Usually this is accomplished by: 1) loading the amount of silage into self-unloading wagons and delivering it to bunk or fence-line feeders; 2) use of automated feeders to deliver a set amount of

feed (controlled by a timing device) into a feeding bunk in the feedlot; 3) by limiting the time during which cattle have access to the self-feeding area; 4) moving silage by front-end loader bucket to bin type feeders; and 5) by hand feeding individual animals (such as diary cows) a given weight of silage once or twice daily.

To increase nutrient intake, silage is often mixed with grain prior to feeding, using a mixing wagon.

In general terms, two thumb rules are used in determining how much silage to feed various classes of livestock.

If substituting silage for hay, (assuming hay is 90% dry matter and silage 30% dry matter) 3 parts of silage is equal to 1 part of hay.

If cattle will consume 2-3 percent of their liveweight daily as "good" to "excellent" quality hay, they should theoretically consume 6-9% of their body weight in the form of similar quality silage when fed on silage alone. This thumb rule may apply to large-framed wintering beef cows but may not apply to younger, animals with a less well developed digestive system. Animals must be closely monitored to determine if intake of silage is adequate to meet nutritional needs.

FEEDING VALUE OF ROUND BALE ALFALFA HAY AND SILAGE WITH AND WITHOUT A PRESERVATIVE

Two experiments were carried out (in successive years) to determine the feeding value of round bale alfalfa hay and silages, with and without the preservative "Silogen". The forage was harvested at 20, 50 and 65% moisture. The hay was stored outside and the two silages stored in sealed plastic tubes. The chemical analyses of the forages and the performance of the growing steers are summarized, averaging years, in Table 6.

There was considerable mold growth in both the silages caused primarily by the entry of air through punctures made by birds and/or animals. While this is a hazard encountered when using the plastic bag silage system, it is preventable. Results should be evaluated in the light of these conditions.

Table 6 A Comparison of Round Bale Hay and Silages, With and Without Silogen, on the Chemical Analyses and Feeding Value of Forages Fed to Growing Steers (Average 2 years data)

Moisture Level at Harvest:	20%		50%		65%	
Additive:	0	+	0	+	0	+
Chemical Analyses (% of DM)						
Dry matter at feeding (%)	83	83	54	54	43	43
Crude protein (%)	15.1	15.1	15.6	15.4	15.4	15.8
Acid detergent fiber (%)	38	40	38	38	38	37
Acid detergent insoluble N (%)	0.16	0.16	0.17	0.16	0.14	0.16
pH	6.0	6.0	5.8	5.7	5.9	5.6
Animal Performance						
Average initial weight (kg)	267	260	258	266	259	261
Average daily gain (kg)	0.65	0.64	0.79	0.78	0.78	0.78
Feed intake (kg/hd/dy)	7.82	7.67	8.29	8.50	8.08	8.15
Feed DM:gain ratio	12.8	12.2	10.6	11.1	10.4	10.6

COMMENTS

1. Addition of the additive had no effect on the chemical analyses of the forages or on animal performance.

2. The higher than optimal pH's for the silages indicates that their was insufficient production of lactic acid. Despite this, the feeding value of the forage put up at 50 and 65% moisture was better than that of the hay put up at 20% moisture. It would appear, at least under the conditions of this test, that a certain degree of spoilage improved the palatability of the forage! Harvesting and storage losses were not measured.

EFFECT OF MOISTURE LEVEL AT HARVESTING, ADDITION OF FORMIC ACID AND OF FEEDING SUPPLEMENTAL GRAIN ON THE FEEDING VALUE OF OAT SILAGE

In each of two consecutive years, forage oats, at the mid-dough stage was swathed and either picked up and ensiled immediately, or allowed to field-wilt before being chopped and ensiled. Half of each silage was treated with formic acid (Chemsil) at the rate of 3.3 kg per wet tonne the first year, while in the second year the direct cut silage was treated with 3.5 kg per tonne and the wilted silage with 5 kg/wet tonne. The forage was put up in bunker silos and covered with black polyethylene sheeting (6 mil). A layer of straw bales was later placed over the silos to protect against freezing.

The silos were opened in early March, and the silage fed to 12 groups of

Table 7 Effect of Moisture Level, Treatment With Formic Acid and Supplementation with Grain on the Performance of Beef Calves fed Oat Silage (2 year average)

	Direct Cut						Wilted					
	No acid			Formic acid			No acid			Formic acid		
Grain/hd/day (kg)	0	1.36	2.72	0	1.36	2.72	0	1.36	2.72	0	1.36	2.72
Average initial weight (kg)	333	332	333	331	333	333	331	331	332	333	334	334
Average final weight (kg)	353	375	386	358	375	389	349	371	381	354	375	390
Average daily gain (kg)	0.28	0.61	0.77	0.38	0.62	0.82	0.25	0.57	0.71	0.30	0.60	0.81
Average daily intake (DM)												
- Silage (kg)	5.2	5.5	5.3	5.8	5.5	5.7	5.8	5.7	5.5	6.1	5.9	4.8
- Grain (kg)	0.1*	1.2	2.3	0.1	1.2	2.3	0.1	1.2	2.3	0.1	1.2	2.3
DM/unit gain	18.9	11.0	9.8	15.4	10.9	9.8	23.5	12.0	11.0	20.3	11.8	8.7
Kg DM (%)												
- Harvested	13372			13292			13160			14311		
- Consumed	8648 (64.7)			9287 (69.9)			9187 (69.8)			9141 (63.9)		
- Spoiled	842 (6.3)			693 (5.2)			1902 (14.5)			1715 (12.0)		
- Rejected	297 (2.2)			214 (1.6)			295 (2.2)			256 (1.8)		
- Left at end of test	1861 (13.9)			2141 (16.1)			138 (1.1)			884 (6.2)		
- Lost in system	1724 (12.9)			956 (7.2)			1641 (12.5)			2315 (16.2)		
Crude protein (%)												
- Into storage	9.1			10.1			9.7			9.9		
- Out of storage	9.2			9.6			9.8			10.2		
Digestible organic matter (%)												
- Into storage	52.6			53.2			52.7			51.5		
- Out of storage	52.0			51.4			50.0			51.0		

*A small amount of grain was fed as a vitamin A carrier

8 yearling steers the first year, and of 12 yearling heifers in the second year. Dry-rolled barley was fed at 0, 1.36 and 2.72 kg per head per day to one group of cattle fed each of the four silages.

The results are summarized in Table 7.

COMMENTS

1. The feeding value of the direct-cut silage was higher than that of the wilted silage. This is contrary to normal findings and is at least partially explained by the period of cool, wet weather which delayed harvesting of the wilted silage for several days after the direct cut silage was harvested in one of the two years of the test. Nevertheless, this is a hazard involved in field wilting in an effort to increase dry matter content.

2. Treatment with formic acid increased rate of gain and feed conversion efficiency for both direct-cut and wilted silage.

3. Feeding grain at either rate, markedly improved the performance of the calves whether fed wilted or unwilted silage, with or without the preservatives, and would be a very desirable practice for wintering calves.

4. Totaling feed losses (spoiled, rejected and losses during storage) reveals that losses were less for the direct cut silage than for the wilted silage (17.7 vs 29.6%) and that the addition of the preservatives to the direct-cut silage reduced losses by 7.4%. Adding the preservatives to the wilted silage had no effect on losses.

5. Under the conditions of this test, the use of the formic acid product as a silage additive was beneficial.

THE EFFECT OF "PACKING" VS "NON-PACKING" OF SILAGES ON THEIR FEEDING VALUE FOR BEEF CATTLE

One of the recommendations which is always given to silage makers is that the silage be well packed, particularly in horizontal silos, in order to exclude air and reduce spoilage. However, in areas with a severe winter climate the amount of freezing occurring in the silo is directly proportional to the density of the silage, other factors being equal. Following a report from the Experimental Farm at Kapuskasing, Ontario, that silage that had not been packed had remained in excellent condition, it was decided to see if this technique would be useful under conditions in the Aspen Parkbelt.

Two experiments were undertaken in successive years, with two bunker silos, each approximately 6 x 15.4 m in area with 2.5 m walls. In the first year each was filled with about 115 tonnes of sweet clover silage (36% D.M.). One was packed during filling while the other was not packed. Once filled, both silos were covered with black polyethylene sheeting (6 mil) and held in

place with fish netting. Temperatures rose to 33 degrees Celsius within 10 days and gradually declined. The pH of the two silages was similar (4.5 and 4.7).

In mid February, the packed and non-packed silages were fed with and without 1.8 kg (4 lb) of grain to steer calves, yearling steers and bred beef cows for 11 weeks. Thirty-two head of each type of animal were divided into four equal groups. The results are summarized in Table 8.

Table 8 The Effect of Packing and Not Packing Sweet Clover Silage and of Feeding a Grain Supplement on Three Classes of Beef Cattle

	Packed Silage		Non-Packed Silage	
	No grain	Grain	No grain	Grain
Steer Calves (242 kg)				
Average daily gain (kg)	0.35	0.76	0.15	0.70
Feed d.m. eaten - silage	4.5	4.3	4.3	4.3
- grain	----	1.6	----	1.6
D.M.:gain ratio	12.9	7.7	27.7	8.4
Yearling Steers (384 kg)				
Average daily gain (kg)	0.26	0.70	0.31	0.72
Feed D.M. eaten - silage	6.0	5.8	5.7	6.2
- grain	----	1.6	----	1.6
D.M.:gain ratio	22.7	10.5	18.2	10.7
Bred Cows (499 kg)				
Average daily gain	0.26	0.72	0.33	0.70
Feed D.M. eaten - silage	5.8	7.3	7.0	6.4
- grain	----	1.6	----	1.6
D.M.:gain ratio	22.0	12.3	21.3	11.4

COMMENTS

1. With the exception of steer calves (which gained twice as fast on the packed compared to the non-packed silage), differences in the performance of cattle on the packed vs non-packed silage were small and inconsistent.

2. In all cases, the feeding of 1.8 kg of grain (90% DM), more than doubled rate of gain and markedly reduced the feed required per unit of gain, while having little effect on silage consumption.

3. Losses amounted to 10.9% in the packed silo (spoilage, 10-15 cm on the top; freezing, 75 cm top and sides). Mild weather in February and March eliminated further losses due to freezing. Losses in the non-packed silo

amounted to 21.4% (30.4% on spoilage on top and sides, with seams of spoiled material throughout, freezing penetrated top and sides to about 30-45 cm).

Another test was conducted in which the two silos were divided lengthwise by fish netting, and half of each silo filled with chopped (approx. 10 mm lengths) sweet clover (35.8% D.M.) and the other half with chopped bromegrass-alfalfa (46.2% D.M.). Material in one silo was thoroughly packed while in the other, no packing was done. Immediately following filling, the silos were covered with two layers of black polyethylene sheeting held in place by whale netting.

Both silos were opened in mid-February and silage fed to yearling steers with 0, 1.8 or 3.6 kg of dry rolled barley per head daily. The results are summarized in Table 9.

COMMENTS (Table 9)

1. Non-packed silage fed without grain, produced lower rates of gain than did the packed silages, but the loss due to freezing and spoilage was much less for non-packed than for packed silage (average 23% vs 34% respectively).

2. Except for the high level of grain feeding, steers gained faster on the brome-alfalfa than on the sweet clover silage. However, the reason for this could well be the higher moisture content of the sweet clover silage.

3. Feeding barley at 1.8 kg per head daily markedly improved both rate of gain and feed efficiency under all treatments but in most cases reduced silage intake. Feeding 3.6 kg of grain per head daily, markedly increased rate of gain and feed efficiency of the steers fed sweet clover but not those fed the brome-alfalfa silage, perhaps, in part, because of diluting the level of dicoumarol, which obviously was present in the non-packed silage, and by increasing ration dry matter content.

4. There was virtually no spoilage in the packed sweet clover silos but the non-packed sweet clover contained pockets of mold throughout, and the top 15 cm was moldy. Brome-alfalfa silage suffered spoilage on the top and sides (15-20 cm) in the packed silage and 7-10 cm in the non-packed silage with pockets of spoiled silage throughout the silo.

5. Freezing penetrated to a depth of 1-1.5 m in the packed silages but only 0.3 m in the non-packed silage. While some of the frozen silage was fed, most of the top 45 cm had to be discarded. Consequently losses due to the combination of freezing and spoilage were higher for the packed silage 34% (mainly due to freezing) than for the non-packed silage (23% mainly due to spoilage).

Table 9 Effect of Packing on the Feeding Value of Sweet Clover and Bromegrass-Alfalfa Silages for 280 kg Steers

	Brome-Alfalfa						Sweet Clover					
	Packed			Non-packed			Packed			Non-packed		
Barley/head/day (kg)	0	1.8	3.6	0	1.8	3.6	0	1.8	3.6	0	1.8	3.6
Average days on feed	64	64	64	64	64	64	64	64	64	49*	49*	64
Average daily gain (kg)	0.63	0.89	0.87	0.56	0.73	0.75	0.50	0.79	0.91	0.40	0.65	0.93
Daily D.M. intake												
- Silage	6.4	4.7	4.9	6.0	5.1	4.4	4.9	5.0	3.0	5.7	4.3	4.1
- Barley	--	1.6	3.1	--	1.6	3.1	--	1.6	3.1	--	1.6	3.1
Total (kg)	6.4	6.3	8.0	6.0	6.7	7.5	4.9	6.6	6.1	5.7	5.9	7.2
DM:Gain ratio	10.1	7.0	9.2	10.7	9.2	10.0	9.8	8.4	6.7	14.3	8.9	7.7
Total D.M. consumed (kg)	8165			7928			8740			8582		
Total D.M. spoiled or frozen kg (%)	4288 (34)			2840 (26)			4421 (34)			2117 (20)		

*One steer died - treatment discontinued.

Recommendations when using bunker type silos

1. Maximize storage efficiency by packing silage, but in the Parkland area, where cold winter temperatures are normally experienced, protect the silage from freezing by covering the top and sides of the silo with a tight layer of straw bales.

2. If opting for not packing, chop finely, aim for about 35% dry matter, pile high and cover with air-tight sheeting as quickly as possible. This will minimize area per unit of silage, exclude considerable air by the packing effect of the weight of silage itself, and minimize exposure to "outside" air. This operation can be successfully carried out simply by piling a "long pyramid" of chopped silage on the ground without the use of retaining walls, although walls would help to reduce surface area and give a better packed base.

3. For faster gains and better gain per unit of dry matter, the feeding of some grain to silage-fed cattle will normally be economically sound, particularly for growing cattle.

STANDARD SQUARE BALE SYSTEM

Putting up hay in the form of small rectangular bales has been a very popular practice in the Aspen Parkbelt for many years due primarily to the reasonable investment in equipment and the convenience of shipping, handling and feeding the package, particularly when feeding smaller numbers of animals or limit feeding hay. While about 70% of commercial hay producers and beef cattle producers now prefer the large round bales, the standard "square" bale is preferred by the majority of dairy producers.

The lowest-cost method of harvesting up to 50 tons of hay a year involves a mower and rake or a mower-conditioner-windrower, a baler, and the use of either trailing wagons or a bale stooker and front-end stook loader to handle the bales from field to storage. For harvesting less than 100 tons a year, a custom operation should be considered, as this may be more economical in the long run than making a large investment in equipment, labor and time.

As with other systems, the moisture content at baling is critical. Optimum moisture content is around 20-30%, depending largely on the forage species, and the drying conditions between the time of baling and placement into storage. Baling alfalfa, for example, at 25% moisture and leaving in the field in 15 bale stooks under good drying conditions will reduce leaf loss while allowing the bales to dry out prior to storage. Crested wheatgrass on the other hand can be baled at a higher moisture content than alfalfa as it will tend to dry out faster. If placing directly into storage, alfalfa should be baled at less than 20% moisture but will undergo considerable leaf loss.

HANDLING BALES

Bale handling methods vary from manually picking up single bales in the field to picking them up with an automatic bale wagon. Methods involving high-cost equipment require less labor and a greater volume of harvested hay to justify the investment. Examples of bale systems are as follows:

1. Drop single bales in field, pick up by hand and load onto a wagon, transport to shed or stackyard and unload onto stack:
   - requires three to four men, and is relatively slow;
   - low investment in equipment;
   - possible exposure of bales to weathering.

2. Load bales from baler directly onto trailing wagons, haul immediately to storage site, unload and stack:
   - requires a minimum crew of six and good organization to assure continuous operation of baler and minimal investment in wagons;
   - low investment in equipment;
   - weathering of bales in field is eliminated.

3. Wagon or truck with bale pickup device; mechanically pick up single bales, manually stack bales on wagon, transport to stacking area, use loading device such as a bale elevator:
   - requires only three men; but slower than 2 as all men travel back and forth with each load;
   - faster than 1 (due to mechanization);
   - possible exposure to weathering.

4. Stook bales with automatic stooker (six-bale) or by hand (up to 21 bales), pick up with stook fork, mounted on tractor, transfer bales to wagon or truck, haul to shed or stackyard and stack.

   Variations:

   (a) Hand-load bales from stooks to wagon and haul to storage.
   (b) Pick up with stook fork, load individual bales onto wagon, haul to storage.
   (c) Pick up with stook fork, load stooks intact onto 70 ft. wagon (200-bale capacity), haul to stackyard, unload with stook fork and stack bales individually.
   (d) Haul stooks to stackyard with stook fork and stack individual bales.
   (e) Pick up stooks with fork attachment capable of holding all bales in place and of being rotated; build stack by placing stooks in two or more abutting rows, then fill in space between rows with inverted stooks; stack can be built as high as fork will reach.

   With a method using stooks:
   - hay can be baled at somewhat higher moisture content, thus reducing possibility of leaf loss when baling dry legume hay

(ideally, hay can be dried in the field and removed to storage before weathering losses occur; if weathering occurs, stooked bales are damaged less than single bales);
- requires one to three men, depending on system;
- some methods require higher investment in equipment;
- operator may leave stooks in field too long, believing they are weather-proof.

5. Bale accumulators or bunchers are used to form a packet of bales to facilitate gathering. An accumulating device, a loading device and vagon or truck are required.

Variations:

(a) Manually load bales from packet of bales onto vagon and haul to storage.
(b) Pick up bale packets with pickup device (fork or clamp) and load onto vagon; transport to storage and transfer to stack with pickup device.
(c) Transport from field to stack with pickup device.

With the accumulator system:
- less manual labor (b and c);
- hay should be dry at baling to allov immediate pickup of bales and removal to storage before weathering occurs;
- requires one to three men.

6. Bale throvers are attached to the baler and toss bales into a trailing vagon with back and sides.

Variations in handling bales once loaded:

(a) Unload and stack by hand.
(b) Unload onto a bale elevator, drop bales in a random stack, cover with plastic.
(c) Unload as in (b), but drop through hole in roof of shed.

With a bale throver:
- bales are brought in immediately (reducing risk of loss due to weathering) so must be dry at time of baling; there could be some leaf loss in legumes due to shattering;
- bales are smaller and easier to lift but harder to stack;
- requires only one or two men;
- relatively low investment in equipment;
- bales must be well shaped and properly tied to withstand handling.

7. Automatic, self-propelled or pull-type bale vagons pick up individual bales and form a stack automatically.

With this system:
- requires only one or two men;
- very high investment requiring large volume (about 1200 tons for

self-propelled model) to keep cost/tonne at reasonable level;
- single bales may be exposed to weathering before being picked up;
- bales must be uniform and well tied to allow efficient handling;
- loads must be carefully handled to form sound stacks that won't topple;
- if square-topped stacks are not placed in sheds, weathering can be more serious than for conventional bale stacks (unless properly topped to allow some shedding of water);
- conventional hay shelters may not be suitable for storing automatically formed stacks.

New developments are occurring in the standard bale system. There is now available a square baler that straddles the windrow, thus reducing the movement of the hay within the baler. A farmer in the U.S. has welded a 2.5 cm (1") diameter rod onto the bale plunger, thus producing a baler with an aeration duct running through the centre. This should help to dry out damp bales. (Whether it will attract mice remains to be seen!)

STORING STANDARD "SQUARE BALES"

Because of their shape and size, standard bales do not shed water as well as round bales. Thus ideally, they should be stacked in a hay shelter. In practice, bales are stored in 15 bale pyramidal stooks, randomly in piles or in stacks of various shapes and sizes. Sloping sides of rectangular stacks inward at the top, gives the appearance of a roof-like structure, but merely provides a number of ledges that catch and absorb precipitation. It is recommended that the top of bale stacks be level and that they be protected with securely-anchored tarps or plastic sheeting extending no further down the stack walls than the top layer of the bales. Air tight covers on hay stacks tend to trap migrating moisture underneath and cause molding. The plastic sheeting or tarp can be held down by a layer of bales or old tires. Spreading some straw or loose hay under the cover to slope from the centre to the sides of the stack, can improve drainage and lessen the possibility that trapped water will find its way into the stack through a puncture. Another method used by flax straw processors, is to place straw bales in rows across the top of a rectangular stack, spaced so that the distance between the centres of the rows is equal to the length of the bales. A solid layer of bales is then placed at right angles over the spaced rows. This technique allows the top layer of bales to dry out quickly following periods of precipitation. Covering good quality hay bales with straw bales in this fashion would eliminate the need to use expensive and difficult-to-tie-down plastic.

Provided bales are well formed (uniform size, well tied) it is wise to build stacks as high as possible (12-16 bales high vs 7-9 bales, for example) so that the cost of covering the stack (or the top spoilage) is less per unit of hay stored. Tall stacks must be of adequate width for stability. Minimum width should be 4 bale lengths and height should be about 1 1/2 times the width. Thus a stack 15 bales high [about 5.2 to 5.5 m (17-18') high] should

be about 3.7 m (12') wide or 5, 76 cm (30") bales wide.

With some stacking systems (bale accumulator) it is suggested that stacks be built leaving a air space through the length of the stack, by leaving a space of about 60 cm (2') between the bottom rovs of bale packs and gradually reducing this distance as successive rovs of packs are added, until the top rovs are tight against each other. This prevents the stack from leaning out and provides a drying "duct" which might be good if the hay was baled on the "tough" side.

FEEDING STANDARD BALES

Standard bales lend themselves to a vide variety of feeding systems. Because of their size and the ease of breaking the bale into hay slices, they can be limit-fed to individual animals (stalled dairy covs), eves in lambing pens, cattle in sick pens, etc., or small groups of cattle, vith a fair degree of accuracy as to the veight fed daily. For large groups, tvines can be removed and vhole bales fed in bunks or on the ground in front of feeding gates or electrified vires; or in the vinter, on frozen ground with little vastage provided amounts are limited to vhat the animals will clean up quickly.

Bales can be placed in self-feeders either loose or intact and "broken" as required. Feeders can be comprised of one or more "tombstone" or slanted-bar feeding gates, preferably designed and managed to encourage cattle to eat with their heads in the feeder. This will discourage them from backing out with a mouthful of hay, vhich they usually drop on the ground and vaste.

Square bales can be easily processed into complete, ground rations using a standard mix-mill, thus increasing their ability to support faster rates of gain with better feed conversion efficiency. It is very important that bales be as dry as possible (10% moisture) so that the cost and time required to grind them will be minimized. This is more likely to be the case, at least in the Aspen Parkbelt, if the bales have been stored under a roof so that moisture lost during storage is not replaced by exposure to precipitation.

The energy required to process rations of various types is shovn in Table 10. Note that grinding baled hay vas more efficient than grinding loose hay from the hay tover, due primarily to the uneven flov of material coming out of the hay tover.

Ground hay-based rations should be full fed, either daily in feed bunks or in self-feeders. Using self-feeders will likely be more efficient for small scale feeding enterprises. Care should be exercised to be certain that heating does not occur in the self-feeder due to a combination of high moisture hay (>15-20%) and the temperature generated in the hammermill, particularly during varm veather.

Table 10 Energy Requirements for Processing Hay vs Grain-Based Rations

Ration		Tractor-Implement	Grinding (1/2" screen) Fuel rate L/t (g/ton)	Grinding (1/2" screen) Work rate t/hr (ton/hr)	Rolling Grain Fuel rate L/t (g/ton)	Rolling Grain Work rate t/hr (ton/hr)	Mixing + Unloading Fuel rate L/t (g/ton)	Mixing + Unloading Work rate t/hr (ton/hr)	Overall Fuel rate L/t (g/ton)	Overall Work rate t/hr (ton/hr)
Br-alf (rec. bale)	- 95%	IHC 1066-NH 359	6.79	3.10			4.45	1.36	10.96	0.95
A.F.A. + minerals	- 5%		(1.36)	(3.41)			(0.89)	(1.49)	(2.19)	(1.04)
Alf. (rec. bale)	- 95%	IHC 1066-NH 359	5.66	3.94			3.48	1.12	8.96	1.31
A.F.A. + minerals	- 5%		(1.13)	(4.33)			(0.70)	(1.23)	(1.79)	(1.44)
Alf. (loose hay from haytover	- 95%	IHC 1066-NH 359	7.21	2.45			2.15	1.93	9.06	1.08
A.F.A. + minerals	- 5%		(1.44)	(2.69)			(0.43)	(2.12)	(1.81)	(1.19)
Barley straw	- 88%	IHC 1066-Bearcat 1260	17.92	1.41	6.01	1.48	1.25	3.09	8.16	1.02
Barley grain	- 10%	(Grinder-mixer with	(3.58)	(1.55)	(1.20)	(1.63)	(0.25)	(3.40)	(1.63)	(1.08)
Minerals	- 2%	hydraulic operated roller)								

(g = gallons)

The ability to more effectively use hay in complete rations by balancing its nutritional excesses or deficiencies with appropriate supplements is facilitated by the processing of such bales through a grinder-mixers, something that cannot be achieved efficiently, as yet, by using the large round bale.

ADVANTAGES AND DISADVANTAGES OF THE STANDARD "SQUARE" BALE SYSTEM

Advantages

1. The basic investment in equipment for small operations compares favorably with other systems.

2. The package is convenient to handle and feed, particularly when feeding small groups of livestock, limit feeding on a daily basis, or when feeding individual animals (dairy cows).

3. The square bale can be conveniently processed by a grinder-mixer and amount of hay used estimated fairly closely by using average bale weights.

4. The system is also well adapted to putting up bedding, thus spreading investment costs over two operations.

5. The square bale is a convenient package to transport.

Disadvantages

1. For small scale operations (with minimal investment in equipment) the labor required to handle bales is high and physically demanding.

2. Square bales must be stored in shelters or properly protected stacks outdoors if weathering losses are to be minimized under conditions prevailing in the Aspen Parkbelt.

3. Automated bale handling equipment (i.e. self-propelled bale wagon) is very expensive, requires a skilled operator to properly handle (including the building of stable stacks) and requires a large operation to justify the investment. In addition, the bales must be uniform in size and well tied.

4. The system requires the use of twine which adds to the cost and creates disposal problems.

5. The moisture content at baling must be lower than for some systems, resulting in higher losses in feeding value.

LARGE SQUARE BALERS

Large square bales, are being used in some areas of the United States, mainly by dairymen and feedlot operators. These bales are easier to ship and handle than conventional bales, provided front-end loader or fork lift equipment is available. Reaction to feeding the bales is mixed. Its more difficult under limited feeding conditions, to determine hov much of a bale to feed, compared to how many standard bales to feed. While the hay bales come apart in layers, they may or may not be easy to feed depending on the situation.

The unprotected bale cannot be stored outside as it is easily penetrated by precipitation. However, "four-bale-high" stacks have been well protected with overlapping 3 meter square caps (10 x 10') of corrugated steel, mounted on tubular steel frames and anchored into the bales by means of pins connected to the cap by means of a short length of chain.

The bales are tied with three rounds of heavy twine.

SUMMARY OF PERTINENT DATA

- Size of bales	1.5 x 1.4-1.5 m x 2.3-2.5 m (59 x 55-61 x 90-91")
- Weight of bales	860 kg (1900 lb) for alfalfa; 545-590 kg (1200-1300 lb) for grass hay
- Density	95-160 kg/m^3 (6-10 lb/cu.ft)
- Harvesting rate	1 3/4 to 6 1/2 minutes per bale or 13.5-18 tonne/hr (15-20 tons/hr)
- Tractor size	37 kw (50 hp) or more
- Twine	three wraps with heavy twine (15 seconds)

PRECAUTIONS

Bales made with the Howard baler are denser at the front and bottom sides, thus must be stacked with the front ends above each other or, if turned, with the bottoms placed above each other, otherwise stacks may collapse.

ROUND BALE SYSTEMS

The large, round hay baler, introduced in the early 1970's has become the most popular hay harvesting machine in Western Canada, with almost 70% of commercial hay producers and beef cattle producers preferring round bales over any other form of packaged hay. Its popularity is based on its low labor requirement (could be a one-person system) both in terms of "manpover" and physical effort, and equipment cost, rather than on the quality of the product.

Two types of round balers, soft and hard core, are available. The hard-core baler has a spring-loaded, adjustable bale chamber that rolls the hay under continuous pressure from start to finish. The soft-core baler has a fixed bale chamber encircled by a number of belts or rollers. The hay in the chambers does not roll until it fills the chamber and exerts pressure on the rollers. The incoming hay is continuously wrapped around the hay mass, which folds the center into a "star" shape. The center is less dense than the perimeter, thus providing better aeration after baling. Both types of balers may use longitudinal belts or metal (horizontal) rollers or bars to form the bales. Bales are wrapped with from 6-15 rounds of either sisal or plastic twine, sisal being preferred with the more slippery material and plastic twine preferred where contact with the ground could cause rotting at sisal twine. Recently a plastic netting wrap has become available.

Narrow-belted balers have more difficulty in starting a bale if the hay or straw is slippery in texture or short. Softer core balers have less difficulty in starting a bale as no rolling is required initially. It may be necessary for the operator to weave the unit from one side of the windrow to the other, when the width of the windrow is less than that of the baler, in order to form a bale of uniform diameter. Belt-type round balers are not recommended for making round bale silage, as belts become wet and slippery after the first few bales are formed.

Compared to the hard-core baler, the soft-core baler requires twice as much fuel. Because it requires higher peak power to maintain pressure on the bale, a larger tractor must be used and operated at the standard PTO speed. For example, when brome-alfalfa hay yielding 5.5 tonne/ha was baled, the hard core baler required 0.99 liters per tonne while the hard core baler used 2.01 L/tonne (see Table 11).

Table 11 Fuel Consumption of Forage Cutting and Baling Systems

Operation	Tractor*	Implement	Fuel Consumption L/ha (gal/ac)	Fuel Consumption L/hr (gal/hr)	Fuel Consumption L/t (gal/ton)	Work Rate ha/hr (ac/hr)	Work Rate t/hr (ton/hr)
Swathing (+ conditioning)		S.P. Versatile 12' swather (Gas)	3.58 (0.32)	8.38 (1.85)		2.34 (5.79)	
Mowing + conditioning	IHC 624	NH 749 Mower-conditioner	6.83 (0.61)	5.81 (1.28)		0.85 (2.10)	
Round baling (br-alf) 0.56 t/ha (0.25 ton/ac)	IHC 1066	McKee 1578 (soft core)		11.80 (2.59)	8.14** (1.63)		1.45** (1.59)
Round baling (br-alf) 0.56 t/ha (0.25 ton/ac)	IHC 684	MF 560 (hard core)		8.80 (1.94)	5.03** (1.01)		1.75** (1.92)
Round baling (br-alf) 5.5 t/ha (2.45 ton/ac)	IHC 986	McKee 1578		12.10 (2.67)	2.01** (0.40)		6.02** (6.64)
Round baling (br-alf) 5.5 t/ha (2.45 ton/ac)	IHC 684	MF 560		4.68 (1.03)	0.99** (0.197)		4.73** (5.21)
Rectangular baling (br-alf) 0.56 t/ha (0.25 ton/ac)	IHC 684	NH 273		11.10 (2.45)	4.89** (0.98)		2.27** (2.50)
Rectangular baling (CAG)	IHC 684	NH 273		6.09 (1.34)	1.00** (0.20)		5.72** (6.30)
Rectangular baling (CAG)	IHC 656 (Gas)	IHC 47		10.05 (2.21)	1.90** (0.38)		5.27 (5.81)

*Diesel tractor unless specified.
**Dry matter weight used.

Source: Dr. E.Z. Jan

Field losses with the hard core baler were 4 percent greater than for the soft core baler. This is believed due to the need to weave back and forth across the swath, which increases pick-up losses.

When stored outdoors, the hard core bales lost less dry matter than the soft core bales (9 percentage points when baled at 23% moisture and 4 percentage points when baled at 15% moisture), but the quality of the hay was not as good.

The lower density of the soft-core baler (Table 12) increases rate of drying compared to hard core-bales, immediately following baling.

Table 12 Effect of Type of Round Baler and Moisture Content on Weights and Densities of Brome-alfalfa Bales

	Dry Matter (%)	Average Weight kg (lb)	Density kg/m³	Density (lb/ft³)	Volume m³	Volume (ft³)
Hard-core	80	491 (1081)	162	(10.4)	3.04	(104)
(Massey Model 560)	75	519 (1142)	175	(11.2)	2.96	(102)
Soft-core	80	535 (1176)	130	(8.3)	4.1	(141)
(McKee Model 1578)	75	552 (1215)	135	(8.7)	4.1	(140)

The results of a feeding trial to evaluate the round bales described in Table 12 are presented in Table 13 (see page 50).

When bales harvested at 15% moisture were stored under a roof, the live weight gain/ha was improved for the hard-core bales with no difference for the soft-core bales.

Improvements in round bale technology are ongoing. Bales can now be automatically tied when the predetermined size is reached and can be unloaded without backing the baler up, starting the next bale on the same spot. Twine can be applied more quickly by using two spools of twine simultaneously. A plastic net material is available to wrap the bale in just over one rotation of the bale. This netting not only reduces baling (tying) time (average 30 sec./bale), but greatly reduces loss of material during transport and helps to shed precipitation. The netting is also much more easily removed than twine at feeding time. It is expected that, before long, balers will be available which can tie/wrap bales and eject them without the need to stop the machine. Some new balers are available that will form bales about half the width of conventional round bales, but with the same diameter. Other models are available which are equipped with knives which slice bales in half within the bale chamber.

Many types of round bale loaders and movers are available, ranging from a grapple fork on a front-end loader to units which automatically load and transport twenty or more bales. Perhaps the simplest, and least costly, is the use of a front-end loader and standard bale racks with either a back wall (when piling bales with their axes at right angles to the length of the rack) or slightly raised edges to prevent bales from rolling off the rack when piled in two rows parallel to the length of the rack, with one row on top.

STORING ROUND BALES

Ideally, round bales should be stored end to end on well-drained ground in long rows, with enough space between the rows to permit good air movement. In most situations, however, bales are usually stacked in a pyramidal configuration (in 3:2:1 rows) to save space. Where precipitation is moderate to heavy, considerable moisture runs off the top rows and down onto the lower rows, resulting in hay spoilage due to molding. Another popular configuration is to place bales on end, one or two high and to place a bale (on its side) on top. However, bales must be tight and well-tied.

On poorly drained land, bales can be placed on old tires, fence posts or poles to keep them off the ground. Otherwise moisture moves from the soil up into the bale and causes spoilage. This also keeps the bales free of stones or dirt, which is particularly important if the bales are to be put though a tub grinder. Protecting round hay bales with plastic sheeting or tarpaulins is very difficult, due to the effort required to keep this material in place during high winds.

When round balers are used to bale high-moisture hay or round bale silage, it is, of course, imperative that the bales be protected (either by covering with plastic sheeting, sealed around the bottom with earth or sand, or by placing in plastic bags or tubes.) The high moisture hay is usually preserved by using anhydrous ammonia (2% of forage wet weight) while the round bale silage is placed quickly into air-tight storage and excess air removed by an industrial type vacuum cleaner. This reduces the oxygen available to bacteria growth. It also reduces temperature rise which attracts cats etc. to claw (rip) their way into the top of the stack/tube, in search of a warm bed.

SLICING ROUND HAY OR SILAGE BALES

Most round bales are fed by placing a whole bale in a bale feeder and removing the twine. Some are unrolled and fed on the ground. Tub grinders, and other types of grinders or shredders, are also available for processing round hay bales. However, some livestock producers wish to break up round bales in order to limit feed them using a feeding gate or bunk feeder, or to process them into complete rations using a grinder-mixer. Breaking apart round bales with a fork is hard work. For this reason research was carried out at the Melfort station to investigate less arduous means of slicing

bales. The two most effective methods were as follows.

Chain saw. A 66 cc Husquarna Model SE 266 chain saw with a 0.9 m (36") blade, cut a bale half-way through quite easily. The bale can be easily halved by slicing from each side. Using a 99 cc engine and a 1.8 m (72") blade, the bale can be cut in half with a single stroke, but requires two people to operate. Key factors are adequate power and high chain speed, which reduces the likelihood of hay jamming the sprocket drive. Removing twine before cutting is necessary. Shape of the teeth did not influence performance. This unit worked well for both hay and silage bales.

Double Band Saw Unit. A round open-ended drum large enough to accommodate a 1.5 m (5') diameter hay bale was mounted on a bale mover. Two band saws, cutting in both directions, were mounted on the bale mover at right angles to each other and spaced to slice the bale into nine sections of approximately equal dimensions. The bale, with twine intact, is placed on the conveyor of the bale mover and moved through the saw blades. The band saw is PTO driven and the tractor hydraulic system is used to power the conveyer. A bale can be sliced in five minutes and emerges in its original shape. Simple systems for conveying the bale sections to feeders or into grinder-mixers have not yet been developed.

FEEDING ROUND BALES

Round bales can be self-fed in place by using an electrified wire or movable (or stationary) feeding gate. Consumption can be roughly controlled by the rate at which the feeding gate is moved or feed pushed up to within reach of the cattle. In small scale feeding situations, the hay can be self-fed in round or rectangular metal or wooden, portable or movable feeders with or without a roof to keep out precipitation.

To improve performance of cattle when fed hay-based rations, round bales can be chopped or ground, using a tub grinder and the feed placed into a self-feeder. This will also reduce wastage, particularly if coarse stemmy hay is being fed, provided leakage of finer hay from the machine, and wind losses from the conveyer are minimized.

If limit-feeding of hay to feedlot cattle is required, there are round bale unrollers or shedders that can convey the hay into bunk or fence-line feeders. Where the ground is frozen or hard, round bales may be simply unrolled, but wastage is high unless it is fed in amounts that are "cleaned-up" quickly.

So far there is no practical method of grinding round bales with standard on-farm grinder-mixer in order to prepare complete rations. Commercial equipment for grinding large round flax straw bales is in use. The grinders are powered by electric motors and can process bales very quickly. Perhaps in the future, such equipment will be used to process hay for commercial scale feedlots.

ROUND BALE SYSTEM DATA

- size of bales	1.23 to 1.9 m (48-75") wide and 1.50-2.15 m (60-84") in diameter
- weight of bales	275 to 1400 kg (600-3100 lb)
- density	145-175 kg/m^3 (9-11 lb/ft^3)
- harvesting rate	5.5-24 tonnes/hr (6-26 tons/hour) (3-4 minutes/bale) Average 9.5 t/hr (10.5 tons/hr)
- tying time	35-120 seconds/bale
- baling losses	0.5-15% (Average 3% for reasonable conditions)
- tractor size	45-65 kw (60-90 hp)
- twine	6-10 wraps (70 m/t-210 ft/ton) for 1.5 x 1.8 m (5' x 6' bales), (50 m/t-150 ft/ton) for 1.9 x 2.1 m (6' x 7' bales)
- plastic net wrap	1 1/2 wraps

Caution:
- A number of serious injuries and deaths have occurred when people have attempted to adjust balers, or to clear away hay buildup while the machine was in motion.
- Round bales have been deposited on steep slopes and rolled, causing broken fences, etc.
- Round bales must be handled with care. Lifting too high, with certain types of front-end loaders (not equipped with a grapple fork) can cause the bale to fall backward onto the operator.
- Dropping round bales into self feeders has killed or injured cattle whose heads were through the feeding gate.

ROUND BALE SYSTEMS

Advantages

1. Low labor requirement (one person could handle it).
2. Reasonable investment in equipment.
3. Good capacity (9-10 t/hr).
4. A reasonably weather resistant package (depending of kind of hay).
5. Can be used to put up bedding and round bale silage.

Disadvantages

1. Bales require mechanical handling due to their weight.
2. Larger bales may not be convenient under limited feeding conditions.
3. Sometimes difficult to form a uniform bale.

4. Not easily processed into ground, complete rations.

5. Doesn't make efficient use of existing square bale shelters, storage takes up a lot of space.

6. Removal of twine at feeding causes problems.

7. Baling and feeding can be hazardous, considerable caution required to prevent accidents.

A COMPARISON OF TWO TYPES OF LARGE ROUND BALERS

A stand of bromegrass-alfalfa hay was swathed in two different years with a mower conditioner and field dried in the windrow to 24% (high) and 19% (low) moisture. Two types of large round balers, one (Massey-Ferguson 560) forming a uniform density, and the other (McKee 1578) a soft core bale, were used to bale the hay at each moisture level. All of the high moisture bales and half of the low moisture bales were stored in single rows without shelter. The remaining half of the low moisture bales was stored under shelter. Field losses, recovery of dry matter following storage, and feeding values for steers, were determined. The results are summarized in Table 13 averaging data for the two years.

Table 13 The Effect of Type of Round Bale, Moisture Level and Storage Method on Field and Storage Losses, and on the Feeding Value of Bromegrass-Alfalfa Hay when Fed to Beef Steers

	High Moisture (24%)		Low Moisture (19%)			
	No Shelter		No Shelter		Shelter	
	Hard Core (Massey)	Soft Core (McKee)	Hard Core	Soft Core	Hard Core	Soft Core
Field losses (%)	12.3	5.2	16.6	16.5	18.2	11.9
Moisture at baling (%)	24	23	18	18	19	19
Dry matter harvested (kg/ha)	3316	3538	3194	3250	3115	3218
% of harvested dry matter						
- consumed, refused, weighed						
- back, or left in storage	95.9	90.9	94.7	92.0	94.2	92.2
Storage losses (%)	4.1	9.1	5.4	8.1	5.8	7.9
Steer feeding trial (84 days - 2 pens of 8 steers per treatment)						
Average initial weight of steer (kg)	244	243	241	243	240	242
Average daily gain (kg)	0.61	0.62	0.62	0.66	0.69	0.61
Average daily dry matter eaten (kg)						
-hay	6.5	6.2	6.2	6.3	6.1	5.9
-grain	0.8	0.8	0.8	0.8	0.8	0.8
Hay dry matter/unit gain*	13.4	12.6	12.7	11.8	10.8	12.3
Kg gain/tonne DM harvested	70.1	71.0	73.0	76.2	85.6	73.6
Kg gain/ha	231	250	232	247	266	236
Chemical analyses (1 year only)						
Into storage						
- Crude protein (%)	15.4	15.2	14.9	15.5	15.3	15.4
- Organic matter digestibility (%)	58.3	59.2	59.3	60.8	57.7	57.7
Out of storage						
- Crude protein (%)	16.1	16.1	16.0	15.5	15.9	16.1
- Organic matter digestibility (%)	53.7	53.1	54.1	52.6	53.6	54.7

*Assuming 6.5 feed conversion for grain portion of ration.

COMMENTS

1. High moisture, soft-core bales stored outside were superior in several respects to the hard-core bales, - lower field losses, better

feed:gain ratio, higher liveweight gain/ha.

2. Field losses (determined for one year only) were affected by precipitation, time in the windrow (between replicated areas in the field) and, for the high moisture hay, by the type of baler. Dry matter losses during storage were about the same for both methods of storage and lower for the uniform density bales (5.6 vs 8.0) than for the soft core bales.

3. Steer calves fed the low moisture, uniform density bales, stored under shelter, had the highest rate of gain, although differences between treatments were not large (0.08 kg/day/head spread). Feed efficiency was also best for that treatment [19% better than for the poorest treatment (high moisture, hard core with no shelter)]. Differences among treatments of up to 8% in gain/ha were obtained

4. There were six replicates laid out in the field for the six different treatments. Total potential yield was determined by harvesting and weighing a strip of standing hay in each replicate with a Haldrop forage plot harvester and carrying out dry matter analyses immediately. In the one year in which field losses were determined, field losses varied between replicates from 0.6% to 32% (average 13.4%) depending on the amount of rain received from cutting to baling for the different harvesting treatments (up to 65.1 mm during a 9 day period and 29.3 mm between cutting the high and low moisture treatments in one replicate). When baled at the higher moisture level, losses were significantly greater with the Massey than with the McKee baler while there were no significant differences in losses due to type of baler when hay was baled at the lower moisture level. Some pickup losses occur with the Massey baler due to the need to weave back and forth along the windrow to achieve a uniform diameter bale and the inevitable missing of some hay, the amount depending on the skill of the operator.

MECHANICAL STACKING WAGONS

The popularity of mechanical stacking wagons has declined considerably since they were introduced in the early 1970's, particularly in the Aspen Parkbelt, where precipitation causes significant spoilage in improperly topped stacks. For purposes of completeness, their use and evaluation under weather conditions experienced at Melfort is briefly outlined here even though some of the equipment is no longer manufactured.

Mechanical stacking wagons are basically of two types, compaction and non-compaction. The compaction models compress the hay by repeatedly (3-8 times) lowering an hydraulically operated roof (Hesston and John Deere models) or by the rolling action of the hay distribution arm (Haybuster Stack Eze). The non-compaction stackers (McKee and Gehl) blow the chopped or shredded hay into the stack former and rely on the vibration of the unit to "compact" the hay. In all cases it is either difficult or impossible for the operator to see what is happening within the stacking chamber and there is little control to assure that the center is well compacted and the hay evenly

spread, particularly with the non-compression units. Even though the stack when deposited, may appear to be well formed, there is often uneven settling of the stack, with depressions serving as funnels to channel precipitation into the stack to cause spoilage. As a result many stacks require "hand-topping" to improve their ability to shed rain or melting snow.

Hay is normally put up at from 25-30% moisture depending on the kind of crop and the density of the stack. In some situations crested wheatgrass has been successfully put up at 35% moisture (small Heston stacks in good drying weather). Putting hay up too dry or too loose makes stack forming difficult and predisposes to losses caused by wind.

Basic information on these systems is summarized as follows.

Stack size:	- round (cup cake shaped)	diameter	3.3 to 5.5 m (11-18')
		height	4.6 to 5.2 m (16-17')
	- rectangular (loaf-shaped)	width	2.1-4.4 m (6.9-14.5')
		length	2.5 to 7.6 m (8-24')
		height	2.5-5.1 m (8-16 1/2')

Stack weights: 0.7 to 7 tonnes (0.8-7.7 tons), depending on size of windrow (speed of packing) type and moisture content of the crop.

Harvesting rates: 3.5 to 13.5 tonnes/hr (3.9-14.9 tons/hr) depending on the size of the windrow, size of stacking wagon, number of compressions and type of crop.

Stack density: 59-95 kg/m^3 (3.8-6.0 lb/ft^3)

Losses: 15-40% or more (shattering losses at loading, wind losses during filling, while in the field, and during moving unconfined stacks, weathering losses during storage and incomplete pickup when moving to feeders.)

STORING HAY STACKS

Stacks are usually deposited in rows (with an air space between) along the edge of the hay field for later pick-up and removal to the feeding area or are hauled directly to the feeding area. Stacks will dry out more quickly (and hence could be put up at a somewhat higher moisture content) if immediately deposited in the field, than if they are transported to the feedlot (due to the increase in density caused by the settling action of the moving unit). There is, however, a possibility of wind loss in newly-deposited stacks and of additional loss is picking up and transporting the unprotected stack vs. transporting directly to the feeding area in the stacking unit.

It is recommended that poorly-formed stacks be "hand-topped" to be sure that the centers are well-packed and the tops sloped and "groomed" to shed water. This is particularly important in the Aspen Parkbelt when precipitation during the storage period can be appreciable.

Stacks should be stored on well-drained ground to minimize absorption of runoff and ground moisture, protected where possible from high winds and lined up in a north-south direction to allow maximum exposure to the sun to speed drying following periods of precipitation.

FEEDING STACKS

Stacks may be self-fed in place or in other areas, by the use of an electrified wire or feeding gates to control access and minimize wastage. They may also be picked up with special loading units (e.g. the floor of the McKee unit) and moved into enclosed feeders which may or may not permit cattle to push in the hinged sides to reach the stack as it is diminishing in size. These movers are tilted and worked under the end of the stack at the same rate as the conveying chains in the floor are moving the stack onto the floor. As in the unloading process, failure to synchronize the movement of the floor under the stack, with the speed of the in-floor conveyer can lead to broken stacks. A stack feeder is also available. It moves the stack into a device at the front of the "mover" which chops off the stack and delivers the hay into a fence line feeder or onto the ground.

In other cases, the hay is removed by a grapple fork on a front-end loader and conveyed to the feeding site as required.

The following are the advantages and disadvantages of the system.

Advantages

1. System can operate with one person and one tractor.

2. No twine is required, reducing costs and eliminating the twine disposal problems.

3. Stacks can be either deposited in the field or taken directly to the feeding site, since the size of the package justifies the trip.

4. The system has good capacity.

5. The system will also handle straw for bedding or feed.

6. Stacks can be baled at slightly higher moisture content then in the case of standard bale.

7. Mechanical stack moving and feeding equipment are available.

Disadvantages

1. A relatively high investment in equipment is required.

2. Compression-type stackers require stopping each time the roof is lowered to compress the stack (15-30 seconds).

3. Considerable operator skill is required to form good stacks and to unload without splitting the stack.

4. Stacks are primarily suited for feeding operations involving long hay and cannot be easily processed into complete, ground rations to improve feeding value.

5. Newly-formed (unsettled) stacks are subject to losses by wind.

6. Because of uneven settling, particularly in the non-compression stack, losses due to spoilage are considerable, resulting in lowered feeding value (quality and palatability) of the hay.

EFFECT OF DROPPING HAY STACKS IN THE FIELD VS IMMEDIATE HAULING TO STACKYARD

A bromegrass-alfalfa stand was windrowed and stacked at 23% moisture using a McKee 800 wagon. Five stacks were dropped in the field and five hauled 2.4 km to the stackyard. Field dropped stacks were hauled into the stackyard 2 months later (during which period of time, storage losses, which would not be measured in this test, would have occurred). The hays were fed to Hereford heifers which also received 0.9 kg of barley daily. Results are shown in Table 14.

Table 14 Effect of Field Dropping vs Transporting Newly-formed Hay Stacks, on Yield and Quality of Bromegrass-Alfalfa Hay.

Method	DM (kg) Into storage	DM (kg) Out of storage	DM loss in storage (%)	Average daily gain of heifers (kg)	Feed/ unit gain	Gain/ ha (kg)
Field dropped	5080	4900	3.5	0.80	9.5	192
Hauled in	5793	5042	13.0	0.72	10.3	180

COMMENT

In this case, the field dropped hay had a higher feeding value than the hay hauled in directly after stacking. DM loss in storage applies to the field dropped stacks only after being brought in, hence are not comparable. In practice the decision on field dropping vs hauling in immediately, will depend on the density and moisture content of the hay and on other operational considerations. Alfalfa at 25% moisture is probably better left in the field. Crested wheatgrass at 18% could probably benefit from the

packing action during transport.

A COMPARISON OF COMPACTION VS NON-COMPACTION STACKING WAGONS

A bromegrass-alfalfa stand was cut with a 2.8 m (9′) mover-conditioner and left in the windrow to dry to about 25% moisture. In was then harvested with McKee 800 (non-compaction) and John Deere (compaction) stacking wagons. Stacks were deposited in the field, and hauled in two months later. The stacks were fed to two groups of 27 Hereford heifers, using an electrified wire around the perimeter of each stack to control wastage. The results are summarized in Table 15.

Table 15 The Effect of Type of Stacking Wagon on the Quality of Bromegrass-Alfalfa Hay

Rated capacity (kg)	Actual capacity (kg)	Dry Matter (kg) Into storage	Dry Matter (kg) Out of storage	DM loss (%)	Animal gain (kg/day)	Feed: gain ratio	Gain (kg/ha)
		John Deere 200 (compaction)					
2727	2045	1334	1362	0	0.43	15.3	348
		McKee 800 (non-compaction)					
3636	2364	1467	1417	3.4	0.40	15.7	313

COMMENT

Visual appraisal found McKee stacks to contain more spoilage than did the John Deere stacks, undoubtedly due to the greater difficulty in putting good, moisture-shedding tops on the stacks made with non-compression stackers.

A COMPARISON OF STANDARD BALING VS STACKING WAGON SYSTEMS

An experiment was carried out to determine the effect on digestibility and intake of three hays when put up using stacking wagons vs the standard baler. The effect of putting the hay up at two different moisture levels, within each system and species of hay, on digestibility was also determined.

The Hesston 30 and McKee 1200 stacking wagons were compared to a conventional baler with the hays, crested wheatgrass, intermediate wheatgrass and bromegrass put up at 20 to 30% moisture in standard bales and 30 to 40% moisture in stacks. Baled hay was stored in stooks in the field for 2-3 weeks, then placed in a hay shelter. Stacks were stored outside.

After winter storage, all crested wheatgrass hay was in fairly good condition. Intermediate wheatgrass stacked at 40% moisture was moldy, particularly in the center of the stacks, with that stacked at 30% moisture containing a small amount of mold. Baled intermediate wheatgrass was in good condition. All bromegrass stacks were moldy while bales harvested at 30% moisture were moldy, and those baled at 20% were in good condition.

The results of the test are summarized in Table 16.

COMMENTS

1. Crested wheatgrass hay (CWG) was superior in feeding value to the other hays, with intermediate wheatgrass (IWG) a close second and bromegrass (BG) definitely inferior. (Protein contents at harvest averaged 11.4, 11.1 and 12.3 for CWG, IWG and BG hays, respectively).

2. Putting up the CWG hay in the form of standard bales resulted in superior feeding value, with the Hesston and McKee stacks of about equal feeding value. With IWG, the Hesston stacks and the standard bales were of about equal feeding value with the McKee stacks slightly inferior. With BG, standard bales were superior in feeding value with McKee stacks producing more palatable hay than the Hesston even though digestibility was marginally lower. A big difference in initial moisture content of stacks compared to bales is probably responsible for the differences in feeding value between the stacks and the bales.

3. Moisture content, averaging the stacking wagon treatments had little effect on the level of digestible dry matter at the time of harvest indicating that at the moisture levels tested, there was no significant saving of fine leaf material by harvesting at the higher moisture level. By the time the hays were fed, the effect of the initial differences in moisture level was variable, with higher in vivo digestibility occurring in the CWG that was put up at the higher moisture level, lower digestibility in the BG that was put up at the higher moisture content (perhaps due to slower rate of initial drying because of the wider leaves) and considerable variation occurring within the IWG due to harvest method and initial moisture content.

4. Decreases in digestibility (in vivo) between harvesting and feeding for CWG, IWG and BG averaged 1.6, 1.3 and 3.6 percentage units, respectively.

Table 16 Effect of Method of Harvesting and Moisture Content on the Digestibility and Intake of Three Grass Hays

Hay	Digestible organic matter (%) At harvest	Digestible organic matter (%) Next spring	In vivo dry Matter digestibility (%)	Matter consumed (hd/day)	Digestible D.M. intake (hd/day) gms
a) Method of Harvesting					
Crested Wheatgrass					
Method: Hesston* "30"	60.2	57.2	58.0	695	404
McKee* "1200"	59.6	57.6	57.1	713	409
Standard baler	60.1	59.4	59.6	735	436
Intermediate Wheatgrass					
Method: Hesston "30"	59.3	58.1	58.6	649	381
McKee "1200"	59.3	57.4	57.8	631	363
Standard baler	58.9	57.8	58.5	645	377
Bromegrass					
Method: Hesston "30"	56.1	52.7	53.0	608	322
McKee "1200"	56.3	51.2	51.8	672	350
Standard baler	56.9	54.1	57.6	745	427

b) Moisture Content at Harvesting

	Moisture (%) At harvest	Moisture (%) Next spring	In vitro organic matter digestibility At harvest	In vitro organic matter digestibility Next spring	In vivo dry matter digestibility (%)
Crested Wheatgrass					
Method: Stacks	35	18	60.0	57.5	58.2
	29	18	59.8	57.3	56.9
Bales	34	12	59.4	59.0	60.4
	19	9	60.7	59.7	58.7
Intermediate Wheatgrass					
Method: Stacks	38	20	59.6	56.0	59.3
	27	21	59.1	59.5	57.1
Bales	27	12	59.6	58.4	57.5
	22	13	58.1	57.2	59.4
Bromegrass					
Method: Stacks	41	19	55.5	50.8	51.7
	31	22	56.9	53.0	53.1
Bales	30	12	56.1	53.1	57.0
	20	14	57.7	55.0	58.1

*Stacking wagons: Hesston - compression type; McKee - non-compression type.

HAY DRYING SYSTEMS

"Barn-dried" hay has long been recognized for its excellent quality. Long or baled hay is placed in a loft or shed over a slatted floor or around drying ducts, through which heated or unheated air is forced by means of a blower. The system is normally very labor intensive and has a low capacity.

In 1971 research was initiated at the Melfort Station to develop and evaluate a hay drying and storage system patterned after the Schwarting hay tower system which is in use in Europe and some middle eastern countries. The goal was to develop a lower cost unit, by using locally available materials, to make it as automated as possible and to develop the management of the unit to permit more rapid filling while achieving a high quality product. These goals have been achieved.

The Melfort hay drying tower shown in Fig. 1 was developed over a ten year period, in cooperation with the Engineering and Statistical Research Institute of Agriculture Canada's Research Branch in Ottawa. The formed hay mass sits on a round concrete base, made up of two semi-circular concrete-walled sections filled with gravel, with a meter wide space between them, which is covered with tongue and groove planking except for a 1.5 m (5") opening in the middle. This "tunnel" accommodates a 7.5 kw (10 HP) fan on the one end, removable baffle to divert the air upward through the hay and an open end (sealed during drying) for the unloading conveyer. A raised [approx. 25 cm (10")], slatted circular floor sits on the concrete and gravel base and extends to about 1 meter from the perimeter of the base.

The metal (granary-type) roof, suspended with a winch system, is supported by 4, H beams, bolted to metal plates anchored in concrete piles set out about 60 cm (24") from the concrete base. The distributing-unloading mechanism [a reversible 28 cm (11") diameter auger in a bottomless V trough] is suspended from the roof (Fig. 2). Chopped forage (7-10 cm lengths) is unloaded from forage wagons into a blower and conveyed through the peak of the roof and deflected onto the auger which conveys the material from the center of the unit outward to the periphery of the tower, leveling the material as it rotates around the top of the "stack". As the unit fills, the roof section is automatically raised by an electric winch system.

Slightly overlapping plywood panels [76 x 122 cm (30 x 48")] are suspended by hinges from the corrugated ring [80 cm (32") high] supporting the roof. The panels are tied together by a cable running through eye-bolts. The cable is tightened during the filling process to keep the panels in a vertical position (to "form" the hay) and loosened during the unloading process to wedge the hay inwards toward the auger. The end of the auger is fitted with a curved knife, during unloading, to loosen the outer hay wall which would otherwise be outside the reach of the auger, because of the expansion of the stack due to settling.

A 1.5 m (5') diameter cylindrical bung about 1.2 m (4') high is suspended from the center of the roof to form a vertical drying duct as it is raised. A canvass skirt, 1.8 m (6') long is attached to the bung at the

Fig. 1 Helfort Hay Tower During Filling.

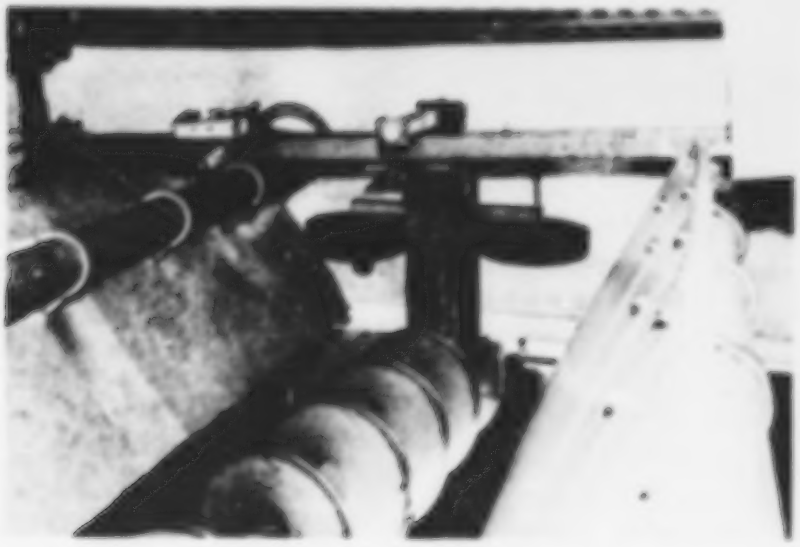

Fig. 2 Single, reversible auger, loading-unloading mechanism in Melfort Hay Tower.

lower end, with a metal ring attached at the bottom. The air pressure pushes the canvass against the hay thus blocking the escape of air around the bung. When filling, the bung unit is kept as low as possible [about 60 cm (2')] below the upper surface of the hay, to encourage a horizontal, rather than a vertical, flow of air.

With the use of a natural gas heater to raise the air temperature about 6°C (10°F) above that of the ambient air, rate of drying can be increased considerably, allowing the unit to be filled in three days, even under unfavorable drying conditions.

Air is forced through the hay until the moisture level drops to 16-18%. As a check on completion of the drying, the fan is turned on early in the morning, after being off the previous night. If moisture and heat can be seen coming out of the stack, drying is not complete. After a few weeks of storage, the moisture level will drop to around 11%, an ideal level if the hay is to be ground for incorporation into complete rations. Drying to 18% moisture is normally completed by a week to 10 days after filling is completed.

A moisture (rain, dew) sensor was developed to automatically shut off the drying fan when drying with unheated air. The fan is activated for a one hour period every four hours during these conditions to prevent overheating of the hay.

When drying is complete, the hung is removed, the auger direction reversed, the cutting knife attached to the end of the auger, the baffle in the tunnel removed and a conveyer placed into the tunnel past the lower end of the vertical drying/unloading duct, to convey the chopped hay into the hammermill of a grinder mixer, or into self-unloading or self-feeding wagons. The following information further describes the tower and its operations.

Height: - base, 1.2 m (4')
- hay above base, 10.5 m (34')
- to peak of roof, 13.8 m (45')
- to top of column brace unit, 15.4 m (50')
- at H-beam columns, 12.3 m (40')

*Diameter of base: 7.6 m (25')
Capacity: 60-75 tonnes of dry matter, depending on the kind of crop and length of cut.
Dry matter range: at filling 60-70%; after drying 82-90%
Filling time: 3-10 days - depending on use of supplemental heat, hay type and the temperature and humidity of ambient air.
Fan: 7.5 kw (10 HP)
Drying time: 2-4 weeks after filling is started.
Estimated cost: around $70,000, (about the same per unit of dry matter capacity as a concrete stave site.)

*Note: The Melfort hay tower was built with a diameter of 7.5 m (25') because this was the diameter of the largest granary roof available at the time. The capacity of the tower could be more than doubled by increasing its diameter to 10 m (32 1/2') and its height by about 1.5 m (5'), which would approximate the size of the Schwarting unit. The increase in cost would be only moderate and would reduce cost per unit of hay stored. Where there was no possibility of flooding (i.e. on a well drained area), construction costs could be reduced by eliminating the concrete base and placing the hay on a concrete slab with drying duct beneath. If available, wooden (treated) poles could replace the H beams but would have to be solidly anchored into the ground and braced on top. The larger unit would require a larger blower [15 kw (20 HP) unit rather than 7.5 kw-10 HP unit now used].

FIELD OPERATIONS

The crop (usually high quality alfalfa, grass or grass-legume mixture to justify the cost of the hay tower) is cut with a mower-conditioner-swather. The hay is field-dried to between 25-40% moisture, depending on the crop (lower moisture with legumes than grasses) and on the weather conditions. It must be remembered that the goal is to reduce field losses due to shattering and that this system is justified only if it is managed to achieve minimal loss of feeding value. On the other hand, placing high moisture hay into the tower causes problems with air movement within the hay due to its greater

density, thus increasing the drying time involved, possible respiration losses and the time required to fill the tover. The moisture content of the hay going into the tover should be as consistent as possible to promote even air flow. (Othervise the air will tend to move through the drier layers in preference to the denser, vetter layers.)

The vindrovs are picked up vith a forage harvester set to cut at maximum length [10-1 mm (4-5")]. The forage is blovn into side-unloading forage vagons and transported to the tover vhere it is unloaded into a blover and conveyed into the tover through the apex of the roof. Filling rate is about 4 tonnes (4.5 tons) of dry matter per hour.

When the layer of chopped hay is about 1.5 m (5') deep, the drying fan is turned on. If the outside air is varm and dry and the material in the tover is under 35% moisture, it may not be necessary to use heated air. However, from the standpoint of permitting rapid filling of the tover, the use of heated air may be desirable. In any event, heated air should be used for overnight operation vhen ambient air in the Aspen Parkbelt region is likely to be cool and humid.

The energy required for hay tover operations is shovn in Table 17.

METHOD OF FEEDING

The chopped, dried hay can be limit-fed "as-is" as a supplement to lov quality roughages (cereal straws) for vintering beef covs. A daily amount of 3.2 kg (7 lb) of alfalfa analyzing 17% crude protein, 1.3% calcium, 60% total digestible nutrients and a vitamin A equivalent of 100 IU/gm (if good green hay) will supply a 500 kg (1800 lb) dry cov in the latter third of her pregnancy vith all her requirements for protein, calcium and vitamin A and 42% of her energy requirements. When nursing a calf, 5.5 kg (12 lb) vould meet her protein, calcium and vitamin A requirements plus 62% of her energy requirements. In addition other minerals are provided.

The hay can also be ground and self-fed "as is" or mixed into complete groving-finishing rations for beef cattle and sheep. For efficient production the higher than required protein level of the hay should be balanced vith high energy supplements.

While ve have not fed hay from the tover to dairy cattle, its high protein level and palatability should be ideal for feeding to high-producing dairy covs.

Hay from the tover has also been pelleted for more compact storage and/or more efficient transportation.

SUMMARY ADVANTAGES AND DISADVANTAGES OF THE HAY TOWER SYSTEM

Advantages

1. Reduced field and storage losses, compared to other systems, results in a high-quality product (Table 17).

2. A fully automated system, requiring only one man at the tower to control rate of unloading into the blower.

3. Unit can be filled in 3-4 days (using heated air) and could be filled 3-4 times during the season if used to produce hay for marketing.

4. The product can be further processed (ground, pelleted) if required. [A positive feeding mechanism (auger) may be required to force the chopped hay into the throat of some grinder mixers.]

5. If required, the hay can be stored in the tower with minimal weathering, less than 2.5 cm (1") for a considerable period of time (at least 2 years). However, it is an expensive storage shed!

6. Compared to a tower silo, there are no problems due to freezing during the winter.

Disadvantages

1. High investment in equipment [hay tower, forage harvester, 3 to 5 forage vagons, depending on hauling distance, one 67-75 kw (90-100 HP) tractor on the forage harvester, two 45 kw (60 HP) tractors to haul and unload the vagons and a blower powered by a 22.5 kw (30 HP) electric motor (or) a 35 kw (45 HP) tractor].

2. Requires a minimum of three operators (one field chopping, one hauling, one unloading).

3. Rate of production is low, 4.2 tonnes (4.6 tons) per hour, compared to some systems and volume is limited to a maximum of 70 tonnes over a 3 to 4 week period with the structure described.

4. A high degree of management is required to assure uniformly good hay quality.

Table 17 Chemical Analyses of Hay Put Up in the Melfort Hay Tower

Location in Tower	Dry matter (%)	Crude protein (%)	Ash (%)	Acid detergent fiber (%)	Acid detergent insoluble nitrogen (%)
	Hay into Storage (Sept. 17, 1987)				
Top layer	72.5	19.9	8.0	28.9	0.19
	Hay out of Storage (Feb. 8, 1988)				
30 cm from center	89.3	23.9	9.7	21.8	0.24
91 cm from center	89.2	23.1	9.7	22.5	0.25
152 cm from center	88.7	21.4	9.0	25.1	0.22
213 cm from center	88.9	18.5	7.9	34.2	0.26
274 cm from center	84.8	17.8	6.6	38.8	0.22
Average (weighted)	87.7	20.0	8.2	30.9	0.24

COMMENTS

1. Protein content was well maintained. Higher readings toward the center of the tower may be the result of fine particles of leaf separation from the hay as it is augered toward the outside of the tower. As the hay is augered out for feeding, protein content would be evened out. This explanation would also account for the higher ash and lower fiber content of the hay in the center of the stack.

2. Cost of drying was $6.60 for electricity and $6.60 for natural gas per tonne in 1987.

FUTURE POSSIBILITIES FOR THE HAY DRYING TOWER

The hay drying tower, while not adopted by farmers to date, may have a role to play in the production of high quality, long-fibre hay to meet the growing demand on export markets. The tower, or a series of towers, could be filled with alfalfa, cut at an appropriate stage of maturity to assure the crude protein content required, dried and packaged into plastic wrapped, securely-tied compacted bales, sized to fit containers used for the export trade. The tower(s) could be filled throughout the season (perhaps 3-4 times), markedly reducing the investment cost per unit of hay dried. The high quality hay would also have a role to play in meeting domestic requirements, particularly of dairy cattle or other livestock operations where the product could be used to supplement lower quality roughages (wintering beef cows) or as part of a growing-finishing ration for ruminant livestock in combination with low protein-high energy supplements such as

acidulated fatty acids, tallow or low quality (cost) canola oil. The product could also be used to advantage in some types of poultry, swine and domesticated rabbit rations.

PRESERVATIVES FOR HAY

Ideally, hay should be cut at the optimum stage of maturity for the livestock operation involved, and dried as quickly as possible to a moisture content that will prevent spoilage. In practice, the time from cutting until the hay is dry enough for baling or stacking is often much longer than optimum, which permits excessive losses due to plant respiration (which occurs above 40% moisture), shattering of leaf material if windrows have to be turned, bleaching and leaching of nutrients (soluble carbohydrates) due to sun and rain (Table 18) and spoilage caused by microbiological activity. Drying time is influenced by the moisture content of the crop at cutting (a function of crop maturity and forage species), the yield of the crop (size and density of windrows), whether or not the hay is crimped or conditioned, and the weather conditions (precipitation, relative humidity, temperature and wind speed).

Table 18 Effect of Rain on Quality of Windrowed Alfalfa at Lacombe*

Time after cutting (days)	Rain (mm)	In vitro digestible organic matter (%)	Crude protein (%)	Acid detergent fibre (%)	Estimated relative feeding value (%)
2	0	67	17	32	124
4	12	68	18	31	128
8	68	65	17	36	111
9	68	64	16	37	108
15	83	63	16	39	98

*Original data rounded to nearest whole number.

Source V.S. Baron

It is generally recognized that field drying hay at less than 20% moisture will result in increasing losses in feeding value due to the loss of leaf material. The losses will be greater (up to twice as much) with legumes as with grasses as the moisture level drops. It is also recognized that baling hay above 25% moisture will increase the dry matter yield but may well result in a reduction in feeding value due to spoilage in storage (molding) particularly if the baler or stacks are exposed to poor drying conditions immediately after harvesting and particularly with legumes. Crested

wheatgrass baled at 37% moisture at Melfort showed minimal spoilage during storage and retained its bright green color.

In many situations it would be operationally as well as nutritionally advantageous to harvest hay at moisture levels above those normally considered safe for storage purposes. If spoilage following baling could be prevented, higher yields per unit of land and higher quality hay could be achieved. The only disadvantage would be if the hay was to be ground for inclusion in complete rations (the major means of improving the efficiency of hay utilization). Grinding hay in excess of 10-12% moisture markedly increases the power required to process the hay and the time involved in processing. The other disadvantage would be the increased cost of transporting the lower dry matter hay.

There are several options available to the forage producer to reduce the time involved in field curing and/or the risk of weathering in the field. Forage can be cut, field-dried to 60-70% moisture and ensiled. It can be cut, field-dried to 35-40% moisture and artificially dried using a loft drying system, aerated hay shed or a fully automated hay-drying tower, or a hay preservative can be used.

Over the years, a number of products have been developed and marketed as hay preservatives. These products kill fungal and bacterial populations that are normally present in hay and which, given favorable moisture and temperature conditions, multiply rapidly and feed on the nutrients in the hay, producing additional heat which further speeds the deterioration of the hay.

Hay preservatives can be classified as chemical or biological. Chemical preservatives include anhydrous ammonia, urea, propionic acid or derivatives. Biological agents (primarily mold inhibitors) include a number of commercial products containing live or dead bacteria, with or without enzyme activity.

Perhaps the most effective of these preservatives is anhydrous ammonia. In 1974, research was undertaken at the Melfort Station to determine the effect of treating alfalfa hay at 35% moisture and bromegrass hay at 30% moisture with anhydrous ammonia at rates of 1 and 2% (wt/wt). Bales were stacked and sealed under polyethylene sheeting. The sheeting was removed at either 4 or 21 days for the alfalfa, and samples analyzed at four months after treatment. Bromegrass hay stacks were sealed (treated) for either one or four months prior to sampling for chemical analysis and feeding to lambs. Untreated high and low moisture stacks served as controls.

The 2% anhydrous ammonia treatment was completely effective in preventing heating and mold growth in both hays during both the treatment period and following the removal of the polyethylene cover. The 1% ammonia treatment reduced, but did not prevent, heat damage and mold growth. Ammoniation increased the crude protein content of all treated hays, the 2% rate causing higher levels than the 1% rate (Table 19). Average increases in the crude protein content of alfalfa were 4.8 and 9% at the 1 and 2% ammonia

Table 19 Effect of Ammoniation on Feeding Value and Moldiness of Hay

Treatment	Alfalfa					Bromegrass				
	Moisture (%)					Moisture (%)				
	Into storage	At feeding	Crude protein (%)	Digestible organic matter (%)	Mold (%)	Into storage	At feeding	Crude* protein (%)	Digestible organic matter (%)	Mold (%)
Lov moisture content	23	21	22	54	33	19	17	12	55	3
High moisture content	35	24	23	51	100	31	17	12	51	91
1% anhydrous ammonia**	35	30	26	53	55	32	27	18	57	26
2% anhydrous ammonia**	37	38	30	58	0	30	27	21	59	0

*At time of feeding.
**Averaging storage/treatment times, (4 and 21 days for alfalfa, 29 and 115 days for bromegrass).

levels respectively, while for bromegrass the corresponding increases were 4.5 and 7.7%.

Retention of added nitrogen varied from 26.5 to 77% depending on the application rate and duration of the treatment period. Applying 2% anhydrous ammonia to alfalfa hay prevented the decreases in organic matter digestibility that occurred during storage in all other treatments.

Ammoniation of bromegrass hay did not affect voluntary intake. Treated hay was readily consumed by lambs and no toxic or other adverse effects were evident. In addition, it increased the digestibility of all components measured, except protein, with increases greater for the 2% than for the 1% treatments and for the 119 day vs the 29 day treatment.

Anhydrous ammonia must be used with caution as the chemical can cause severe damage to the skin, eyes and lungs on contact. It is important that the chemical be distributed uniformly throughout the hay for efficient and effective results.

Under certain conditions, the ammonia can react with feed constituents to form a toxic compound, believed to be 4-methyl-imidazol. If consumed by cattle it can cause a nervous disorder referred to as "bovine bonkers". Affected cattle lose control of their movements and may run into fences etc. Removal or dilution of the offending feed will stop the problem. At Melfort two or three animals in a group of around 30 head exhibited this symptom, indicating that either they were particularly succeptible, or that they consumed a portion of the feed that received more than average amounts of ammonia. The problem seems to occur when high quality forage is treated.

Urea can also be used at levels around 2 to 5% to preserve high moisture hay. It is safer to use than anhydrous ammonia, as it depends on the presence of the enzyme urease to hydrolyze it into ammonia and CO_2. Because it is a granular material, it is more difficult to achieve a uniform application than is the case with anhydrous ammonia. Urea poisoning can also occur it animals consume unevenly treated hay.

Propionic acid has been used as a preservative for hay, silage and high moisture grain. Recommended rates vary from 0.5 to 1.5% (w/w) of propionic acid for moisture levels ranging from 25 to 35% (heavier rate with higher moisture contents), but research at the Lacombe Research Station indicated that, for effective control of mold in large round bales treated under field conditions, a rate of 0.5% at 25% moisture hay and 1.13% at 30% would be required.

Propionic acid is highly corrosive and, if spilled onto the skin, should be immediately washed off with lots of water. New products are available that have been neutralized and both diluted (30% propionic acid) and concentrated (60% and more) products are available.

At Lacombe, concentrated (neutralized) propionic acid applied at 1.25%

(w/w) to large round alfalfa bales ranging in moisture content from 13.8 to 25.2%, under ideal weather conditions improved organic matter and protein yields by 3.8 and 3.0%, respectively.

Biological preservatives are available on the market, but their mode of action is not known and research conducted at the Lacombe station found little or no value in their use.

In summarizing work on hay preservatives at the Lacombe Research Station, Dr. V.S. Baron states,

"The research ... indicated the economic margins for improving harvest yield and nutrient recovery after storage with a moist-hay preservative system are small. Above 20% moisture, the field loss rate of dry matter is not high as moisture level decreases. Preservatives can improve forage quality and nutrient recovery but not to the level of dry, rain-free hay. Therefore, effective preservatives must become less expensive or mold control must improve to become economically efficient under all conditions. The moist hay- preservative system becomes more cost effective when the hay is destined for high production rations or for sale, and when rain damage to dry hay is a distinct possibility.

"Of the preservatives available, anhydrous ammonia and concentrated propionates are the most effective, although both have disadvantages and may not always be economical. Dilute propionates are relatively expensive per unit propionate and should only be used in good storage environments (small bales, slightly moist hay, dew) where cosmetic effects are desired. Biological preservatives have some advantages (economical, safe) but their inconsistency and lack of known mode of action make them difficult to recommend at this time."

EVALUATION OF SOME FORAGE HARVESTING SYSTEMS

Considerable information has been published on the engineering and operational aspects of forage harvesting systems (Forage Harvesting Systems, Agricultural Engineering Services Section, Family Farm Improvement Research. Saskatchewan Agriculture, Regina, S4P 3V7). However, little research has been carried out to evaluate the product of the system when fed to beef cattle. Because of this the Melfort Research Station undertook a six-year study to compare several forage harvesting systems in terms of beef cattle gains, individually and per hectare of crop (bromegrass-alfalfa). Initially four systems were evaluated (Table 20a.). At the end of the first three years, two additional systems were added (Table 20b.).

The systems were as follows:

1. Standard square bale - field-dried to 20% moisture, baled and stored under a shelter.

2. Silage - field-dried to 65% moisture, finely chopped and ensiled in a bunker silo.

3. Chopped and dried in a hay tower - field-dried to 40% moisture, long-chopped (10-15 cm), blown into the Melfort hay tower and dried with heated or ambient air in the first three year comparison, and with unheated air during the second three-year comparison.

4. Long, mechanically stacked hay - field-dried to 25% moisture, stacked with a compression type stacking wagon (Hesston 10) and stored outside.

5. Long-chopped, mechanically stacked hay - field-dried to 25% moisture, stacked with a non-compression type stacking wagon (McKee 800).

6. Large round bale system - field-dried to 20% moisture, baled with a Massey 560 large round baler (belt type) and stored singly outside.

Each of the forages was fed to two groups of eight heifers each (first three years - systems 1-4) or two groups of eight steers each (second three years - systems 1-6), on an ad libitum basis. Dry rolled barley was fed at the rate of 0.91 kg/head/day, and the animals had free access to water, salt and mineral mix over the 12 week feeding period during the winter following the haying season.

The results are summarized in Tables 20a and 20b.

Table 20a Comparison of Four Harvesting Systems (Average of First Three Years of Test

	Silage	Chopped dried hay (hay tower)	Mechanically stacked hay (McKee)	Standard bales
Total DM* harvested (kg)	28046	25363	25541	24948
Moisture at harvest (%)	63.8	35.3	26.9	18.5
Total DM				
- offered (kg)	18739	19608	20836	18140
- consumed (kg)	18314	19236	18988	18049
- wasted or spoiled (kg)	4190	260	1868	70
- left at end of test (kg)	3288	2741	1992	10037
- lost in system (kg)	2254	3126	2693	3208
% wasted, spoiled or lost	23	13	18	18
Average daily gain (kg)	0.66	0.69	0.57	0.62
Average daily DM eaten (kg)				
- forage	5.86	6.14	6.09	5.77
- grain	0.77	0.77	0.77	0.77
DM:gain ratio	10.1	10.1	12.1	10.5
Gain/tonne DM harvested (kg)	84	96	77	97
Gain per ha (kg)	406	447	334	436
% crude protein				
- at harvest	11.3	10.6	11.0	10.8
- when fed	11.8	10.8	11.5	11.1
% OM** digestibility				
- at harvest	56.2	57.4	57.1	55.8
- when fed	52.4	53.2	51.3	53.9

*Dry matter
**Organic matter

COMMENTS

1. Highest wastage, spoilage, plus "other" system losses occurred with the silage treatment and lowest with the hay drying tower system. Field losses were not determined but would be expected to be proportional to the dry matter content at harvest.

2. Heifers fed the tower-dried hay gained faster and produced the most gain per ha, but gains per tonne of hay harvested were similar for cattle fed the tower-dried and the standard baled hay.

Table 20b Comparison of Forage Harvesting Systems (Average Second Three Year Test)

	Silage	Chopped dried hay (hay tover)	Mechanical Stacking Wagon		Bales	
			Compression	Non-compression	Regular	Large round
Total DM* harvested (kg)	19135	15036	14196	17976	10459	12056
DM per ha (kg)	4775	4520	4559	4509	4390	4221
Moisture at harvest (%)	65.6	37.5	25.1	24.5	21.2	20.2
Total DM (kg)						
- offered	7538	7713	8053	8499	7722	7954
- consumed	7198	7279	7278	7783	7303	7313
- refused or spoiled	2801***	434	776	716	420	641
- left at end of test	7216	5324	4878	7615	2149	3453
- lost in the system	1920	1999	1264	1862	587	649
% refused, spoiled or lost	25	16	14	14	10	11
Average daily gain (kg)	0.72	0.68	0.58	0.58	0.60	0.57
Average daily DM eaten (kg)						
- forage	5.19	5.25	5.25	5.61	5.27	5.27
- grain	0.78	0.78	0.78	0.78	0.78	0.78
Kg DM/kg gain	8.3	8.9	10.4	11.0	10.1	10.7
Forage DM/kg gain**	8.6	9.3	11.0	11.7	10.6	11.2
Kg gain/tonne DM harvested	83.5	90	75	70	85	77.5
Kg gain/ha	402	399	342	314	369	328

*Dry matter
**Assuming TDN of barley at 83% (DM basis).
***85% due to freezing.

COMMENTS

1. Highest "refused, spoiled or lost" material occurred with the silage system, mainly because of freezing. In contrast to the earlier test, losses were higher for the hay tover system than for the non-compression stacked hay the standard bale. In this test, the stacking vagon losses were higher than for the bale systems.

2. Best rate of gain occurred with steers fed silage or "hay-tover" hay (average 0.7 kg/head/day), with little difference in rate of gain between the stacking and baling treatments (average 0.58 kg/head/day).

3. Gain per tonne of dry matter harvested, was highest for the steers fed the "hay tover" hay and lowest for those fed the non-compression stacked hay, despite high intake of the non-compression stacked hay.

4. Gain per hectare was highest, and similar, for the silage and "hay tover" hay fed steers, and lowest for the "non-compression" stacked hay considerably higher for the steers fed the regular bales than for those fed the large round bales.

5. The relative reduction in the feeding value of the hay tover hay compared to the first three-year test may have been due to the use of unheated air rather than heated air, which lengthened the drying period.

GENERAL COMMENTS FOR BOTH TESTS

The project demonstrated that economically important differences in the feeding value of the product can occur between forage harvesting systems under a given set of environmental and management conditions.

It must also be recognized that the effect on feeding value of the product within forage harvesting systems can be markedly influenced by the management of the process. For example, the large losses due to freezing of the silage could have been avoided by insulating the bunker silo with straw bales or other types of cover. Variations in the moisture content and stage of maturity (nutrient composition) at harvesting can have a marked effect on harvesting losses, feeding value and spoilage during storage. Speed of drying and care to avoid physical losses when filling the hay drying tover can affect handling and storage losses. (In one year the bung support broke, leaving the bung stuck in the hay tover below optimum depth, resulting in some spoilage due to restricted air movement.) The weather experienced in the field between cutting and harvesting can have a profound effect on field losses and feeding value. If standard baled hay is put up under ideal conditions and placed in a shed, there is no reason why its feeding value should be much less than that of hay put up in the hay drying tover. The conscientiousness of the operator in minimizing field and handling losses (incomplete pick-up of windrow losses due to mis-directed spouts on equipment, plugging of blower, etc.) is essential to efficient harvesting.

We would have to conclude that under the right combination of weather and management conditions, it is possible to put up excellent quality forage with minimal field and storage losses using any forage harvesting system. The chances of that condition happening, the cost and convenience of the available system, and the importance of good quality, will, in the end, determine the best system for an individual enterprise.